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# Ranking of educational innovation of the State governments of Mexico: An analysis with the ordered weighted average operator

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**Abstract.** This study aims to classify the educational innovation of Mexico's state governments using the ordered weighted averaging (OWA) operator and its extensions. This method generates a ranking of the Mexican federal entities and constructs an educational innovation index. The results indicate that Mexico City has the highest evaluation levels, while Baja California Sur ranks lowest. Applying this technique not only enables these territories to be ranked according to the relative importance of each criterion, but also produces alternative scenarios that underscore the relevance of these elements. Therefore, the information is valuable for policymakers, as it supports the allocation of resources based on areas of opportunity. Finally, the document illustrates the application of the OWA operator and its extensions to classify the educational innovation of Mexico's state governments.
**Keywords:** Educational innovation, OWA operator, educational innovation index.

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## 1. Introduction

According to Serdyukov (2017), education is important to fulfills the needs of society and is essential for its survival and prosperity. It should be comprehensively sustainable but must continuously evolve to meet the challenges of the fast-changing and unpredictable globalized world. Since the 1990s, a growing volume of literature has explored various aspects of educational innovations in different geographical contexts (Cai, 2017).

Mexico, where the government spends 5.3% of its Gross Domestic Product (GDP) on education (OECD, 2023), is no exception. The recent trend of incorporating educational innovation in higher education institutions in Mexico and Latin America—as a category, strategy, or institutional purpose—should motivate us not to uncritically accept proposals developed in other contexts and cultures without first examining them and attempting to generate our own versions (Blanco Guijarro & Messina Raimondi, 2000).

Therefore, this document reviews educational innovation, reflecting on its measurement based on different models and indicators. Innovation and evolution are essential for individuals, nations, and humanity to survive and progress. Innovations in education are particularly important because education plays a crucial role in creating a sustainable future (Ma & Cai, 2021).
The need for educational innovations has become more pressing. It is widely believed that the social and economic well-being of countries will increasingly depend on the quality of education for their citizens. The emergence of the so-called knowledge society, the transformation of information and media, and the increasing specialization of organizations require high-skill profiles and levels of knowledge (Cornali, 2012).

In this sense, reference is made to United Nations Educational, Scientific and Cultural Organization (UNESCO) definition of educational innovation: change, problem-solving, the active role of the student, and the importance of social interactions in teaching and learning (Moreira et al., 2020). Likewise, it is relevant to highlight the role that he international organization assigns to educational innovation as a path towards the transformation of teaching and learning contexts (Mogollón, 2016).

Educational innovation is a fundamental part of the development and progress of any society. This is why evaluating and classifying the efforts and results of state governments in this area is vital (OECD, 2016). The objective of this article is to classify the educational innovation of the state governments of Mexico through the ordered weighted average operator (OWA) and its extensions. To apply this tool, the indicators proposed by Powell & Snellman (2004), Krstikj et al., (2022), European Bank for Reconstruction and Development (EBRD) (2019), and Chen & Dahlman (2005)—such as the number of researchers, published articles, and authorized patents—will be used. These theoretical approaches are employed because they are the most widely recognized in measuring educational innovation and quality improvement in educational institutions.

This information can be used to understand the country's educational landscape, and it is relevant because it allows us to evaluate how state governments are addressing educational challenges and promoting creativity and intelligence in classrooms. Finally, this approach exposes a more flexible and adaptable way of measuring this variable through these aggregation operators.

This document begins with an introduction where the research objective is stated, followed by a theoretical framework that reviews the literature on the measurement of educational innovation globally and in Mexico. The following section presents the methodology used to measure the educational innovation of the state governments of Mexico through the ordered weighted average (OWA) operator, considering the 32 states of Mexico and the 10 indicators proposed for this research. Finally, the document concludes with a discussion and conclusions

## 2. Theoretical Framework

### 2.1. A literature review of educational innovation measurement

Innovation is perceived as a rupture or change in the assumptions and practices of actors and institutions, which are not random or deliberate but require intent and planning to improve situations that may be problematic (Macchiarola & Juárez, 2014). According to Zabalza Beraza (2004), innovating means introducing justified changes. Thus, innovating in teaching entails the application of three conditions: openness, updating, improvement, and flexibility, to drive progress in educational processes. The author also highlights two essential conditions for university innovation: practicality and feasibility (i.e., concrete results that can be implemented).

For Rubia-Avi (2022), education is one field of human action subject to such influences because innovation emerges when education transforms through technological processes, even if sometimes the way it uses these technologies is not entirely positive. In fact, the transformation of educational and innovation-driven processes through technology has also involved a procedural makeover and a change in our approach to evaluating/researching the benefits these processes bring about.

Educational innovation has been studied from various perspectives. For example, Mykhailyshyn et al. (2018) describe different approaches to interpreting educational innovations and innovations in education. They mention that educational innovations include pedagogical innovation, scientific and methodological innovation, and educational and technological innovation. Innovation in education is a broader concept than educational innovation and includes educational, scientific, technological, infrastructural, economic, social, legal, administrative, and other innovations. In this paper, they employ a qualitative methodology to review scientific approaches.

For their part, Moreira et al. (2020) analyze the conditions that promote and hinder educational innovation in universities from the perspective of teachers and students. A qualitative study was conducted to gather insights from teachers and students at two Latin American universities: Universidad Nacional de Río Cuarto (UNRC) in Argentina and Universidad del Atlántico (UA) in Colombia. Eighteen teachers (eleven from UA and seven from UNRC) and 32 students (22 from UA and 10 from UNRC) from the special education and psychopedagogy bachelor's degree programs participated in the study.

Under these conditions, the role of technology as a tool for innovation is investigated. Most testimonies link educational innovation with ideas of changing, improving, transforming, and breaking traditions and structures. Both teachers and students agree on the importance of implementing innovation in university classes to avoid traditional practices that lead to teacher monotony and student demotivation.

In this context, Pascual Medina & Navío-Gàmez (2018) describe how teachers in schools and high schools in Chile understand the concept of educational innovation. This study used an interpretive-phenomenological paradigm, favoring an inductive analysis with a holistic perspective. It was a qualitative research study in which structured interviews were applied to teachers in Chile to explore the meaning and elements that enhance or hinder educational innovation. The results suggest that teachers conceive educational innovation from a practical-reflective paradigm but feel conditioned by a system that barely surpasses a technological paradigm.

It is evident that educational innovation has managed to capture the attention of academics; however, most of the literature focuses on describing different approaches (Mykhailyshyn et al., 2018) or qualitative studies (Moreira et al., 2020; Pascual Medina & Navío-Gàmez, 2018).

Castellanos Contrera et al. (2020), in their research titled "Fuzzy Logic-Based Model for he Construction of High-Quality Conditions in the Education System," propose that expert systems (fuzzy logic) using tools like digital transformation can self-regulate through intelligent information systems. They present a model based on computational intelligence for managing intelligent information. It integrates several hybrid architectures in a multilevel system and shows results with high-quality metrics, management indicators, values, possible attrition, responses, and plans. This model can influence decision-making, student retention, the knowledge required by the environment, pedagogical innovations, inferred plans, policies, and continuous improvement objectives to strengthen the university's digital transformation. The article presents a transition between theory and software development toward the experimental part without conclusive data.

Halász (2018), in his article, presents the results of a national education sector innovation survey in Hungary. A conceptual and analytical framework for studying innovation processes in the education sector, as well as a data collection tool, were created in a research project on the emergence and spread of local/school-level innovations (the "Innova Research"). This tool collected data from nearly 5,000 educational units across all subsystems of the national education system. A composite education indicator was created, allowing for the comparison of innovation activity across various groups of educational units. Data showed a relatively high level of innovation activity in all subsystems, with significant differences between groups. Connecting the Innova database with data from the regular national pupil achievement survey also made it possible to analyze the relationship between innovation activity and performance. Factors influencing the innovation activity of educational units, such as dynamic organizational capacities, participation in development interventions, and the combination of various forms of innovation, were identified.

In contrast, Cifuentes & Herrera Velásquez (2019) proposed a scale to measure the institutional factors essential to promote educational innovation with Information and Communication Technology (ICT). The scale shows internal consistency in the sample of public school teachers in Cundinamarca (Colombia) with a high Cronbach's alpha. Their work presents four dimensions that can be decisive in understanding these institutional conditions. Technological leadership is key to managing innovation with ICT and appropriating ICT policies at the institutional and individual levels. The dimension of technological leadership holds the most significant relevance for educational innovation. The central contribution of this work is the provision of a valid and reliable scale ($\alpha = .96$) with metric properties that are useful for the community of researchers focused on ICT in education.

For the measurement or evaluation of educational innovation, some authors have used tools such as fuzzy logic (Castellanos Contrera et al., 2020), innovation research (Halász, 2018), and/or scales to measure the essential institutional factors for promoting this evaluation (Cifuentes & Herrera Velásquez, 2019). There are few, if any, studies that analyze educational innovation using the OWA tool, which allows these territories to be ordered according to the relative importance of each criterion and also allows for the assessment of the relevance of these elements.

Thus, relevant proposals are the works of Powell & Snellman (2004), Krstikj et al. (2022), EBRD (2019), and Chen & Dahlman (2005), where the authors propose various indicators as determinants of educational innovation, such as the number of researchers, published articles, authorized patents, number of Higher Education Institutions (HEIs), number of students enrolled in HEIs, number of teachers in HEIs, number of current Conacyt scholarship holders, number of computers, Internet users, and total spending on information technologies. These theoretical approaches have been widely used to define the indicators that drive educational innovation and quality improvement in educational institutions. Consequently, some indicators extracted from these methodologies are used in this study.

## 2.2. Educational Innovation of Mexico

In Mexico, Macías (2005) conducted a study in which he addresses educational innovation from its conceptualization based on five axes: 1) conceptual approach to educational innovation; 2) innovation models from a process perspective; 3) areas of educational innovation; 4) the state of the art on educational innovation; and 5) elements for a theory of Educational Innovation. The analysis concludes with a comprehensive conceptualization of educational innovation.

Macías (2005) summarizes that although educational innovation is present in educational policy and curricula, its implementation must ensure innovative experiences. However, these experiences have not been subject to evaluation or systematization, making it impossible to maintain a general or partial record of the innovative practices carried out in Mexico.

On the other hand, Cuenca et al., (2007), in their research on educational innovation at the National Polytechnic Institute, mention that innovation is considered a strategy to advance the achievement of institutional goals. This work presents the criteria and phases that characterize educational innovation and guide the innovation process, as well as the figures involved in it. The study also addresses those elements that allow for the formation and development of a culture of innovation, which distinguishes the institution for its innovative character.

For Hernández Romo et al., (2021) innovation is most frequently used in the business, technological, social, and educational fields. This results in the term having a polysemic character, acquiring different meanings depending on the context in which it is used. Some studies indicate that, within universities, it is difficult to reach a consensus on its meaning. Through qualitative research with focus groups consisting of teachers and interviews with UNAM officials, the authors explored the meaning of innovation and educational innovation within their academic community, applying a social constructionist approach. The results show that these meanings are diverse and influenced by the contextual aspects of the various knowledge disciplines, which shape different perspectives.

Moyano (2004) conducted research using a qualitative methodology to refer to innovation processes aimed at modifying teaching practices in primary schools. Based on studies on school change processes, he discusses the dominant approach and the treatment of these processes within the framework of current educational policies. He contrasts the features of primary schools and their teachers with the demands arising from the Mexican educational reform of the 1990s.

As the authors mention, the disarticulation of innovations from the institutional and organizational parameters that govern the functioning of schools is a key issue. Additionally, the importance of context in shaping teaching practices is highlighted. Ezpeleta asserts that the current approach prioritizes the technical treatment of these initiatives, limiting them to their internal logic, while marginalizing the political aspects involved in their implementation. This marginalization hinders the alignment of these innovations with the contexts of schools.

In this sense, as well as in the international context, few studies in Mexico related to educational innovation present relevant indicators for analyzing these concepts in universities. The studies conducted thus far have focused on its conceptualization (Macías, 2005), the culture of innovation (Cuenca et al., 2007), and qualitative studies (Moyano, 2004).

## 3. The ordered weighted average operator

An operator that can be used to aggregate information is the OWA (Ordered Weighted Average) operator, introduced by Yager (1988). This operator allows you to aggregate information between the maximum and the minimum, and since its introduction, many applications have been made (Beliakov et al., 2007; Yager & Kacprzyk, 2012). The definition is as follows:
Definition 1. An OWA operator of dimension n is a mapping OWA: $R^n \rightarrow R$ with an associated weight vector W of dimension n such that $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [0,1]$, according to the following formula:
where $b_j$ is the jth largest element of the collection $a_i$.

$$\mathrm{OWA}(a_1, a_2, \dots, a_n) = \sum_{j=1}^{n} w_j b_j, \tag{1}$$

It can be distinguish between the descending OWA (DOWA) and the ascending OWA (AOWA) operator. This difference is related by $\mathrm{w_j} = \mathrm{w^*_{n-j+1}}$, where $\mathrm{w_j}$ is the jth weight of the DOWA operator, and $\mathrm{w^*_{n-j+1}}$ the jth weight of the AOWA operator.

Decisions within OWA operators can be generated under different criteria, the most important of which are the following:

1. Optimistic criterion. It assumes that the most favorable state will be presented so that the most favorable result of each alternative must be selected, and from the results obtained, the most favorable of all. In such a way that this criterion is based on a maxim that is formulated:

$$Decision = Max\{E_i\} = Max\left[Max\{a_j\}\right] \quad (2)$$

2. Pessimistic or Wald criterion. It maintains that the decision-maker must select the best security, so our decision must be the most favorable result among the most unfavorable for each alternative. This method is known as max min, and its formula is:

$$Decision = Max\{E_i\} = Max\left[Min\{a_j\}\right] \quad (3)$$

3. Hurwics criterion. It consists of weighing the best and worst cases, respectively, with an optimistic coefficient and another pessimistic one; subsequently, the values are added, and the alternative that proposes a better result is chosen. The formula for this criterion is:

$$Decision = Max\{E_i\} = Max\left[Max\{a_j\}\right] \quad (4)$$

where $\alpha + (1 - \alpha) = 1$.

4. Laplace's criterion. It is based on the principle of insufficient reason in such a way that the same degree of probability is associated with the different scenarios, provided that there are no indications to the contrary. The formula is:

$$Decision = Max\{E_j\} = Max[(1/n)\textstyle\sum_{j=1}^{n} a_j] \quad (5)$$

## 5. Measurement of educational innovation of the state governments of Mexico with the OWA operator

Some steps must be followed to classify the educational innovation of the state governments of Mexico using the OWA operator:
Step 1: The objective is to classify Mexican state governments based on their educational innovation. This will be the main element, which has been defined by ten indicators derived from the theoretical framework (see Table 1).

**Table 1**. Indicators to measure educational innovation of the state governments of Mexico

| Identifier | Description |
|---|---|
| NOR | Number of researchers |
| PUA | Published articles |
| AUP | Authorized patents |
| NHE | Number of higher education institutions |
| NSR | Number of students registered in HEI |
| NTI | Number of teachers in HEI |
| NCC | Number of current CONAHCYT scholarship holders |
| NUC | Number of computers |
| INU | Internet users |
| TEI | Total expenditure on information technologies |

Step 2: For each of the indicators proposed in Table 1, information was gathered from each of the 32 state governments of Mexico (see Table 2). The data are presented in Table 3.

**Table 2.** State governments of Mexico

| Identifier | State governments |
|---|---|
| A1 | Aguascalientes |
| A2 | Baja California |
| A3 | Baja California Sur |
| A4 | Campeche |
| A5 | Chiapas |
| A6 | Chihuahua |
| A7 | Distrito Federal |
| A8 | Coahuila |
| A9 | Colima |
| A10 | Durango |
| A11 | Estado de México |
| A12 | Guanajuato |
| A13 | Guerrero |
| A14 | Hidalgo |
| A15 | Jalisco |
| A16 | Michoacán |
| A17 | Morelos |
| A18 | Nayarit |
| A19 | Nuevo León |
| A20 | Oaxaca |
| A21 | Puebla |
| A22 | Querétaro |
| A23 | Quintana Roo |
| A24 | San Luis Potosí |
| A25 | Sinaloa |
| A26 | Sonora |
| A27 | Tabasco |
| A28 | Tamaulipas |
| A29 | Tlaxcala |
| A30 | Veracruz |
| A31 | Yucatán |
| A32 | Zacatecas |

**Table 3.** Results of each identifier for each state government

| Identifier | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|---|
| NOR | 290 | 1089 | 271 | 197 | 430 | 625 | 8993 | 583 | 227 |
| PUA | 189 | 710 | 177 | 128 | 280 | 408 | 5864 | 380 | 148 |
| AUP | 2 | 10 | 2 | 0 | 3 | 1 | 149 | 8 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NHE | 64 | 172 | 42 | 73 | 224 | 169 | 500 | 182 | 50 |
| NSR | 62661 | 149726 | 25342 | 40432 | 124559 | 148769 | 849320 | 131823 | 27323 |
| NTI | 5,467 | 12,187 | 2,623 | 2,676 | 7,837 | 11,518 | 72,480 | 11,446 | 2,764 |
| NCC | 494 | 534 | 534 | 557 | 557 | 1,140 | 3,602 | 1,140 | 494 |
| NUC | 702971 | 2071875 | 394307 | 430265 | 1416237 | 376873 | 1719110 | 1900744 | 5140628 |
| INU | 1047284 | 2907894 | 611578 | 660407 | 2220917 | 581013 | 2349450 | 2699056 | 6854170 |
| TEI | 393519 | 1159823 | 220731 | 240860 | 792801 | 210971 | 962347 | 1064025 | 2877692 |
| Identifier | A10 | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A18 |
| NOR | 243 | 1821 | 1104 | 193 | 526 | 1985 | 863 | 1132 | 173 |
| PUA | 158 | 1187 | 720 | 126 | 343 | 1294 | 563 | 738 | 113 |
| AUP | 4 | 21 | 11 | 0 | 8 | 28 | 3 | 10 | 0 |
| NHE | 101 | 554 | 266 | 180 | 141 | 308 | 277 | 160 | 50 |
| NSR | 59561 | 540228 | 198138 | 84018 | 114880 | 286039 | 134981 | 74567 | 51726 |
| NTI | 5,786 | 43,261 | 15,155 | 5279 | 10416 | 26077 | 11895 | 8467 | 2835 |
| NCC | 1,140 | 3,601 | 3,601 | 3602 | 1087 | 495 | 494 | 362 | 494 |
| NUC | 803668 | 2366707 | 1206826 | 1296294 | 4036653 | 8888173 | 1592382 | 899386 | 528314 |
| INU | 1214847 | 3736905 | 1865094 | 1759256 | 6139076 | 12199453 | 2798733 | 1389959 | 811800 |
| TEI | 449889 | 1324868 | 675574 | 725657 | 2259694 | 4975545 | 891406 | 503471 | 295747 |
| Identifier | A19 | A20 | A21 | A22 | A23 | A24 | A25 | A26 | A27 |
| NOR | 1532 | 365 | 1277 | 882 | 158 | 768 | 592 | 806 | 289 |
| PUA | 999 | 238 | 833 | 575 | 103 | 501 | 386 | 526 | 188 |
| AUP | 62 | 1 | 21 | 12 | 0 | 4 | 1 | 8 | 2 |
| NHE | 247 | 148 | 348 | 113 | 63 | 109 | 142 | 163 | 87 |
| NSR | 284942 | 82524 | 312755 | 96940 | 51932 | 98972 | 161482 | 128808 | 88786 |
| NTI | 18871 | 7448 | 19115 | 9635 | 4391 | 6396 | 10651 | 10203 | 6077 |
| NCC | 1141 | 1087 | 1087 | 3602 | 557 | 3602 | 534 | 534 | 558 |
| NUC | 2805077 | 1408822 | 2575736 | 1117022 | 844397 | 1146457 | 1452070 | 1598867 | 1003192 |
| INU | 4375919 | 1988925 | 3698493 | 1572950 | 1326909 | 1719685 | 2241239 | 2429049 | 1414758 |
| TEI | 1570265 | 788650 | 1441881 | 625302 | 472688 | 641780 | 812860 | 895036 | 561581 |
| Identifier | A28 | A29 | A30 | A31 | A32 | | | | |
| NOR | 390 | 177 | 920 | 766 | 305 | | | | |
| PUA | 254 | 115 | 600 | 499 | 199 | | | | |
| AUP | 6 | 0 | 7 | 5 | 0 | | | | |
| NHE | 201 | 61 | 383 | 136 | 80 | | | | |
| NSR | 140675 | 37777 | 249379 | 86276 | 57865 | | | | |
| NTI | 10539 | 3676 | 16565 | 8169 | 4131 | | | | |
| NCC | 1140 | 1087 | 1087 | 558 | 1140 | | | | |
| NUC | 1715783 | 621005 | 3074350 | 1039185 | 633242 | | | | |
| INU | 2628433 | 855607 | 4526127 | 1581369 | 933199 | | | | |
| TEI | 960485 | 347635 | 1721003 | 581730 | 354485 | | | | |

Source: Prepared by the authors with information extracted from CONAHCYT (2022) and INEGI (2023).

Step 3. An evaluation of each indicator based on values between 1 and 10 was done to analyze the results better. To normalize the information, the formula that was used is $10 \times \left(\frac{goverment\ score - minimum\ value}{maximum\ value - minimum\ value}\right) + 1$, being government score is the specific value for the state, minimum value the lowest score and maximum value the highest score in each indicator. The results are presented in Table 4.

**Table 4.** Normalization of each identifier for each state government

| Identifier | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|---|
| NOR | 1.13 | 1.95 | 1.12 | 1.04 | 1.28 | 1.48 | 10.00 | 1.43 | 1.07 |
| PUA | 1.13 | 1.95 | 1.12 | 1.04 | 1.28 | 1.48 | 10.00 | 1.43 | 1.07 |
| AUP | 1.12 | 1.60 | 1.12 | 1.00 | 1.18 | 1.06 | 10.00 | 1.48 | 1.06 |
| NHE | 1.39 | 3.29 | 1.00 | 1.54 | 4.20 | 3.23 | 9.05 | 3.46 | 1.14 |
| NSR | 1.41 | 2.36 | 1.00 | 1.16 | 2.08 | 2.35 | 10.00 | 2.16 | 1.02 |
| NTI | 1.37 | 2.23 | 1.00 | 1.01 | 1.67 | 2.15 | 10.00 | 2.14 | 1.02 |
| NCC | 1.37 | 1.48 | 1.48 | 1.54 | 1.54 | 3.16 | 10.00 | 3.16 | 1.37 |
| NUC | 1.34 | 2.79 | 1.02 | 1.06 | 2.10 | 1.00 | 2.42 | 2.61 | 6.04 |
| INU | 1.36 | 2.80 | 1.02 | 1.06 | 2.27 | 1.00 | 2.37 | 2.64 | 5.86 |
| TEI | 1.34 | 2.79 | 1.02 | 1.06 | 2.10 | 1.00 | 2.42 | 2.61 | 6.04 |
| Identifier | A10 | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A18 |
| NOR | 1.09 | 2.69 | 1.96 | 1.04 | 1.37 | 2.86 | 1.72 | 1.99 | 1.02 |
| PUA | 1.09 | 2.69 | 1.96 | 1.04 | 1.37 | 2.86 | 1.72 | 1.99 | 1.02 |
| AUP | 1.24 | 2.27 | 1.66 | 1.00 | 1.48 | 2.69 | 1.18 | 1.60 | 1.00 |
| NHE | 2.04 | 10.00 | 4.94 | 3.43 | 2.74 | 5.68 | 5.13 | 3.07 | 1.14 |
| NSR | 1.37 | 6.62 | 2.89 | 1.64 | 1.98 | 3.85 | 2.20 | 1.54 | 1.29 |
| NTI | 1.41 | 6.24 | 2.61 | 1.34 | 2.00 | 4.02 | 2.19 | 1.75 | 1.03 |
| NCC | 3.16 | 10.00 | 10.00 | 10.00 | 3.01 | 1.37 | 1.37 | 1.00 | 1.37 |
| NUC | 1.45 | 3.10 | 1.88 | 1.97 | 4.87 | 10.00 | 2.29 | 1.55 | 1.16 |
| INU | 1.49 | 3.44 | 1.99 | 1.91 | 5.31 | 10.00 | 2.72 | 1.63 | 1.18 |
| TEI | 1.45 | 3.10 | 1.88 | 1.97 | 4.87 | 10.00 | 2.29 | 1.55 | 1.16 |
| Identifier | A19 | A20 | A21 | A22 | A23 | A24 | A25 | A26 | A27 |
| NOR | 2.40 | 1.21 | 2.14 | 1.74 | 1.00 | 1.62 | 1.44 | 1.66 | 1.13 |
| PUA | 2.40 | 1.21 | 2.14 | 1.74 | 1.00 | 1.62 | 1.44 | 1.66 | 1.13 |
| AUP | 4.74 | 1.06 | 2.27 | 1.72 | 1.00 | 1.24 | 1.06 | 1.48 | 1.12 |
| NHE | 4.60 | 2.86 | 6.38 | 2.25 | 1.37 | 2.18 | 2.76 | 3.13 | 1.79 |
| NSR | 3.84 | 1.62 | 4.14 | 1.78 | 1.29 | 1.80 | 2.49 | 2.13 | 1.69 |
| NTI | 3.09 | 1.62 | 3.12 | 1.90 | 1.23 | 1.49 | 2.03 | 1.98 | 1.44 |
| NCC | 3.16 | 3.01 | 3.01 | 10.00 | 1.54 | 10.00 | 1.48 | 1.48 | 1.54 |
| NUC | 3.57 | 2.09 | 3.33 | 1.78 | 1.49 | 1.81 | 2.14 | 2.29 | 1.66 |
| INU | 3.94 | 2.09 | 3.41 | 1.77 | 1.58 | 1.88 | 2.29 | 2.43 | 1.65 |
| TEI | 3.57 | 2.09 | 3.33 | 1.78 | 1.49 | 1.81 | 2.14 | 2.29 | 1.66 |
| Identifier | A28 | A29 | A30 | A31 | A32 | | | | |
| NOR | 1.24 | 1.02 | 1.78 | 1.62 | 1.15 | | | | |
| PUA | 1.24 | 1.02 | 1.78 | 1.62 | 1.15 | | | | |
| AUP | 1.36 | 1.00 | 1.42 | 1.30 | 1.00 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| NHE | 3.79 | 1.33 | 6.99 | 2.65 | 1.67 |
| NSR | 2.26 | 1.14 | 3.45 | 1.67 | 1.36 |
| NTI | 2.02 | 1.14 | 2.80 | 1.71 | 1.19 |
| NCC | 3.16 | 3.01 | 3.01 | 1.54 | 3.16 |
| NUC | 2.42 | 1.26 | 3.85 | 1.70 | 1.27 |
| INU | 2.59 | 1.21 | 4.06 | 1.77 | 1.27 |
| TEI | 2.42 | 1.26 | 3.85 | 1.70 | 1.27 |

Step 4: The next step is to determine the weights of each element. To do this, an expert was consulted with the following question: What weight would you assign to each of these criteria, considering their importance for educational innovation? Also, to a person to be included as an expert for this paper two different criterias were used: a) experience in educational innovation and b) experience in administrative positions that have involved decision-making in strategic areas regarding the design and implementation of educational programs. In this case, the person that was considered had more than 10 years in both criterions. An important note that was explained is that the weights cannot be assigned as $\frac{1}{n}$ or 10%, because that will mean that all the elements are equally important and the results obtained will be the average, so the expert must consider even the slightest difference between the relative importance of the indicators. The results are presented in Table 5.

**Table 5.** Weigts related to each element

| Identifier | Weight |
|---|---|
| NOR | 0.14 |
| PUA | 0.13 |
| AUP | 0.12 |
| NHE | 0.1 |
| NSR | 0.09 |
| NTI | 0.08 |
| NCC | 0.07 |
| NUC | 0.06 |
| INU | 0.05 |
| TEI | 0.16 |

Step 5: Using the information provided in Table 4 and Table 5, different aggregation operators can be applied to calculate the evaluation of educational innovation in each state, followed by the creation of the national ranking. The aggregation operators that will be used are Average (A), Weighted Average (WA), $OWA_{max}$ operator (optimistic criterion), $OWA_{min}$ operator (pessimistic criterion) and finally, an interval value (IV) based on Moore (1966) technique is used to unify the results obtained from the other 4 methods, this is done to incorporate in one results all the information that was obtained from different techniques and the formulation for the 4-tuples formulation is $IV = (c_1 + 2c_2 + 2c_3 + c_4)/6$ (Merigó et al., 2016; Xu & Da, 2002). The results are presented in Table 6, and the rankings in Table 7.

**Table 6.** Results using different aggregation operators

| **State** | **A** | **WA** | $OWA_{max}$ | $OWA_{min}$ | **IV** |
|---|---|---|---|---|---|
| A1 | 1.30 | 1.28 | 1.33 | 1.26 | 1.29 |
| A2 | 2.32 | 2.30 | 2.52 | 2.13 | 2.31 |
| A3 | 1.09 | 1.08 | 1.13 | 1.05 | 1.09 |

| | | | | | |
|---|---|---|---|---|---|
| A4 | 1.15 | 1.13 | 1.21 | 1.10 | 1.15 |
| A5 | 1.97 | 1.91 | 2.22 | 1.73 | 1.95 |
| A6 | 1.79 | 1.72 | 2.07 | 1.52 | 1.77 |
| A7 | 7.63 | 7.86 | 8.56 | 6.62 | 7.69 |
| A8 | 2.31 | 2.20 | 2.54 | 2.09 | 2.28 |
| A9 | 2.57 | 2.42 | 3.22 | 1.97 | 2.53 |
| A10 | 1.58 | 1.50 | 1.75 | 1.42 | 1.55 |
| A11 | 5.02 | 4.65 | 5.94 | 4.15 | 4.90 |
| A12 | 3.18 | 2.91 | 3.84 | 2.59 | 3.10 |
| A13 | 2.53 | 2.23 | 3.20 | 1.94 | 2.44 |
| A14 | 2.90 | 2.71 | 3.39 | 2.43 | 2.84 |
| A15 | 5.33 | 5.13 | 6.39 | 4.31 | 5.27 |
| A16 | 2.28 | 2.23 | 2.59 | 1.99 | 2.27 |
| A17 | 1.77 | 1.81 | 1.92 | 1.62 | 1.78 |
| A18 | 1.14 | 1.12 | 1.17 | 1.10 | 1.13 |
| A19 | 3.53 | 3.47 | 3.79 | 3.28 | 3.51 |
| A20 | 1.89 | 1.79 | 2.10 | 1.68 | 1.86 |
| A21 | 3.33 | 3.22 | 3.69 | 2.98 | 3.30 |
| A22 | 2.65 | 2.39 | 3.17 | 2.21 | 2.58 |
| A23 | 1.30 | 1.26 | 1.37 | 1.23 | 1.29 |
| A24 | 2.55 | 2.28 | 3.11 | 2.06 | 2.47 |
| A25 | 1.93 | 1.87 | 2.10 | 1.75 | 1.91 |
| A26 | 2.05 | 2.02 | 2.22 | 1.89 | 2.04 |
| A27 | 1.48 | 1.44 | 1.56 | 1.40 | 1.47 |
| A28 | 2.25 | 2.12 | 2.51 | 1.99 | 2.21 |
| A29 | 1.34 | 1.27 | 1.48 | 1.21 | 1.32 |
| A30 | 3.30 | 3.14 | 3.79 | 2.83 | 3.25 |
| A31 | 1.73 | 1.72 | 1.82 | 1.64 | 1.73 |
| A32 | 1.45 | 1.38 | 1.60 | 1.31 | 1.43 |

**Table 7.** Ranking based on different aggregation operators

| Ranking | State | A | State | WA | State | $OWA_{max}$ | State | $OWA_{min}$ | State | IV |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A7 | 7.63 | A7 | 7.86 | A7 | 8.56 | A7 | 6.62 | A7 | 7.69 |
| 2 | A15 | 5.33 | A15 | 5.13 | A15 | 6.39 | A15 | 4.31 | A15 | 5.27 |
| 3 | A11 | 5.02 | A11 | 4.65 | A11 | 5.94 | A11 | 4.15 | A11 | 4.90 |
| 4 | A19 | 3.53 | A19 | 3.47 | A12 | 3.84 | A19 | 3.28 | A19 | 3.51 |
| 5 | A21 | 3.33 | A21 | 3.22 | A30 | 3.79 | A21 | 2.98 | A21 | 3.30 |
| 6 | A30 | 3.30 | A30 | 3.14 | A19 | 3.79 | A30 | 2.83 | A30 | 3.25 |
| 7 | A12 | 3.18 | A12 | 2.91 | A21 | 3.69 | A12 | 2.59 | A12 | 3.10 |
| 8 | A14 | 2.90 | A14 | 2.71 | A14 | 3.39 | A14 | 2.43 | A14 | 2.84 |
| 9 | A22 | 2.65 | A9 | 2.42 | A9 | 3.22 | A22 | 2.21 | A22 | 2.58 |
| 10 | A9 | 2.57 | A22 | 2.39 | A13 | 3.20 | A2 | 2.13 | A9 | 2.53 |
| 11 | A24 | 2.55 | A2 | 2.30 | A22 | 3.17 | A8 | 2.09 | A24 | 2.47 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 | A13 | 2.53 | A24 | 2.28 | A24 | 3.11 | A24 | 2.06 | A13 | 2.44 |
| 13 | A2 | 2.32 | A13 | 2.23 | A16 | 2.59 | A16 | 1.99 | A2 | 2.31 |
| 14 | A8 | 2.31 | A16 | 2.23 | A8 | 2.54 | A28 | 1.99 | A8 | 2.28 |
| 15 | A16 | 2.28 | A8 | 2.20 | A2 | 2.52 | A9 | 1.97 | A16 | 2.27 |
| 16 | A28 | 2.25 | A28 | 2.12 | A28 | 2.51 | A13 | 1.94 | A28 | 2.21 |
| 17 | A26 | 2.05 | A26 | 2.02 | A5 | 2.22 | A26 | 1.89 | A26 | 2.04 |
| 18 | A5 | 1.97 | A5 | 1.91 | A26 | 2.22 | A25 | 1.75 | A5 | 1.95 |
| 19 | A25 | 1.93 | A25 | 1.87 | A20 | 2.10 | A5 | 1.73 | A25 | 1.91 |
| 20 | A20 | 1.89 | A17 | 1.81 | A25 | 2.10 | A20 | 1.68 | A20 | 1.86 |
| 21 | A6 | 1.79 | A20 | 1.79 | A6 | 2.07 | A31 | 1.64 | A17 | 1.78 |
| 22 | A17 | 1.77 | A6 | 1.72 | A17 | 1.92 | A17 | 1.62 | A6 | 1.77 |
| 23 | A31 | 1.73 | A31 | 1.72 | A31 | 1.82 | A6 | 1.52 | A31 | 1.73 |
| 24 | A10 | 1.58 | A10 | 1.50 | A10 | 1.75 | A10 | 1.42 | A10 | 1.55 |
| 25 | A27 | 1.48 | A27 | 1.44 | A32 | 1.60 | A27 | 1.40 | A27 | 1.47 |
| 26 | A32 | 1.45 | A32 | 1.38 | A27 | 1.56 | A32 | 1.31 | A32 | 1.43 |
| 27 | A29 | 1.34 | A1 | 1.28 | A29 | 1.48 | A1 | 1.26 | A29 | 1.32 |
| 28 | A23 | 1.30 | A29 | 1.27 | A23 | 1.37 | A23 | 1.23 | A1 | 1.29 |
| 29 | A1 | 1.30 | A23 | 1.26 | A1 | 1.33 | A29 | 1.21 | A23 | 1.29 |
| 30 | A4 | 1.15 | A4 | 1.13 | A4 | 1.21 | A4 | 1.10 | A4 | 1.15 |
| 31 | A18 | 1.14 | A18 | 1.12 | A18 | 1.17 | A18 | 1.10 | A18 | 1.13 |
| 32 | A3 | 1.09 | A3 | 1.08 | A3 | 1.13 | A3 | 1.05 | A3 | 1.09 |

Step 6: In this step, the analysis of the results is presented. Based on the results in Tables 6 and 7, a study will be conducted focusing on the top 5, bottom 5, and middle 5 states. This approach allows for a better understanding of how the ranking shifts across different segments. For the top 5 states, it is observed that the top 3 states maintain the same rank across all aggregation operators. However, states ranked 4 and 5 consistently appear in four out of the five operators, with the exception of the $OWA_{max}$.

For the case of the middle States, the ranking between 14 to 18 was considered, and the rank remained the same in W and IV, presenting a change between number 14 and 15 in the case of the WA, but when the $OWA_{max}$ and $OWA_{min}$ operators are used, and the ranking presents essential changes. Finally, for the bottom 5 States, numbers 32 and 31 remain the same in all the aggregation operators, and from numbers 28-30, they change based on the operator that is considered.

An important consideration is that the results can change drastically based on the weighting vector. This limitation, however, is also one of the main strengths of these methodologies. In real-life decision-making processes, the relative importance of each criterion depends on the specific context of the evaluator. In this sense, the results allow states to identify which criteria they need to focus on to improve their educational innovation, based on their unique circumstances, rather than merely taking actions aimed at improving their rank.

## 5. Conclusions

This article presents a classification of the educational innovation of the state governments of Mexico using the ordered weighted average (OWA) operator and its extensions, a fuzzy systems tool that allows different levels of educational innovation to be compared based on varying weighting vectors. The analysis demonstrated that, with the OWA operator, it is possible to obtain a ranking of Mexican state governments according to the importance of each criterion.

The results indicate that Distrito Federal is the federal entity with the highest levels of educational innovation, while Baja California Sur had the lowest evaluation. In this context, using this instrument presents an opportunity for policymakers, as it enables the identification of factors that need more attention, the recognition of areas with the best performance, and the allocation of resources based on areas of opportunity.

For future research, the application of more complex aggregation operators b should be explored, such as the weighted OWA (Cheng et al., 2009; Flores-Sosa et al., 2021), prioritized OWA (Espinoza-Audelo et al., 2021; Yager, 2009), simple additive weigthing (Huesca-Gastélum & León-Santiesteban, 2021), among others. Additionally, a broader analysis should be conducted using information from different educational institutions or countries worldwide.

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