Journal of Innovation & Knowledge 8 (2023) 100439

Journal of Innovation & Knowledge

https://www.journals.elsevier.com/journal-of-innovation-and-knowledge

Education in Mexico and technological public policy for developing complex thinking in the digital era: A model for technology management

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A R T I C L E I N F O

Article History:
Received 20 July 2022
Accepted 13 September 2023
Available online 21 September 2023

Keywords:
Basic education
Educational innovation
Higher education
Complex thinking
Technology management

A B S T R A C T

Currently, numerous studies highlight the importance of technology as an effective resource for improving the quality of education. Like other countries in the region, Mexico greatly emphasizes improving its education system comprehensively and competitively, and technology has become a fundamental strategy to achieve this goal. Technology has allowed it to fill existing gaps and introduce innovative models in the digital age, promoting human capital development and fostering thriving communities. Technology also facilitates the development of competencies, such as complex thinking and the skills required to utilize Education 4.0 resources. However, these advances are at risk without examining the possibilities for technology transfer in the region's educational institutions. Accordingly, the following questions arise: a) What is the probability of achieving technology transfer to primary education institutions; b) What investments or modifications are necessary in the existing infrastructure to transfer educational and other technologies? We aimed to develop a quantitative data analysis model to examine the capacity of primary education institutions, applicable also to higher education, to adapt, assimilate, and transfer technology to improve educational quality in Mexico, as proposed by González Sabater in 2011. The results suggest the feasibility of a technology management system validated through a reliable database, considering the existing infrastructure as a basis for technology transfer. This research is relevant in establishing the probability of success of an educational institution in completing the process of assimilation and technology transfer, thus also contributing to governmental decision-making on educational spending.

Introduction

Quality education is relevant in Mexico and abroad to a growing demand for education to be comprehensive, proactive, and competitive under international standards, which have gained a foothold in influential policy circles worldwide. The COVID-19 health emergency bolstered the use of technology to carry on school activities. Moreover, improving the quality of education using technology has become a recurring topic. Already, several studies discuss the need to access educational resources and open scientific and technological information (Alfaro-Ponce et al., 2023; Huang et al., 2020). Holbrook (2019) emphasizes the opportunity open access offers the educational community. However, open access is intrinsically related to technological assets, which leads us to discuss the importance of technological access as a human right and a public agenda item.

In Latin American countries, improving education at all levels reflects the different stages of history through the various policies promoting it as a priority. However, according to the OECD, ECLAC and CAF (2015), and OECD (2020), these efforts have been insufficient, and educational system enhancements remain inadequate. In simple terms, Latin-American countries, including Mexico, are still in the lower ranks in the studies published by the OECD (2015) and CEPAL (2021). Moreover, their improvements in the rankings are almost imperceptible, suggesting that educational policies in this hemisphere are deficient.

This study addresses two critical issues in this context: deficient education policy performance and limited access to technology. First,

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https://doi.org/10.1016/j.jik.2023.100439

it seeks to understand the ease with which primary education institutions can adopt technology transfers. Second, this study sets out to identify the types of investments or modifications to existing infrastructure that can facilitate educational technology transfer. Thus, if the intention is to generate a public policy involving educational technology to improve education, this study aims to identify the most impactful changes in infrastructure and technology adaptation to improve the teaching-learning process.

International organizations are developing new ways of cooperation to contribute to educational enhancements. One initiative sets the pace for most countries: the 17 proposed Sustainable Development Goals (SDGs) to be achieved by 2030. Concerning education, goal number four highlights the necessity of attaining inclusive and quality education to reach the other goals (UNPD, 2019). The right to education must be perceived from a multidimensional perspective where different actors, such as institutions, families, and society, merge (Muñoz-Ibáñez et al., 2020). In addition, societies and governments need to consider this fundamental right as paramount for realizing other rights. In this context, all civil, political, economic, social, and cultural rights are better enjoyed when people receive minimum education (UNESCO, 2019).

The conventional view to assess the importance of education in some countries focuses on key quantitative indicators. For instance, some early studies emphasize the relationship between educational expenditure and its provision (Ontiveros Jiménez, 2001). Another literature subset evaluates government budget allocations for primary education (Moreno-Moreno, 2008). Yet a third literature stream compares salaries and private income in education as significant indicators for educational dynamics (Urciaga García & Almendarez Hernández, 2008). In Mexico, the strategies proposed by the Secretariat of Public Education (SEP, by its Spanish acronym) to increase educational quality have been considered incomplete for some decades. According to OECD data (Vincent-Lancrin et al., 2017), Mexico's changes in national education quality indicators are almost unnoticed as performance remains deficient compared to other OECD members. However, education coverage for early childhood has improved significantly, and through legal changes intended to impact younger generations directly, SEP has made upper secondary education compulsory (Weiss, 2015).

The Mexican government recurrently states that education should be competitive, inclusive, and high-quality. Nevertheless, decreasing government investment directly affecting technological deployment for educational reforms and its policy objective to encourage students to pursue technical education continues to hamper progress, rendering it almost imperceptible in international indicators (Villafaña-Infante et al., 2021). This situation is critical given existing international evidence of a positive correlation between significant use of educational technology and higher academic performance on PISA tests in various countries (Skryabin et al., 2015; West, 2013).

In contrast, developed societies continue to bolster technology in education. Recent trends emphasize the development of competencies in higher education for decision-making to face highly globalized digital markets (Ji et al., 2023). Thus, the development of specific applications between industry and higher education institutions to generate, transfer, and commercialize technological systems has gained prominence (Abbas et al., 2019; Klauss, 2000). These partnerships have resulted in new public agenda priorities targeting specialization in areas such as health sciences education (Yael, 2020). Considering this dynamic in developed societies, it is crucial to highlight that, increasingly, any public policy aiming to improve education must ponder the use of educational technology, its insertion into existing technological infrastructure, and its application as an enabler to achieve quality education.

Due to the above, this work proposes building a model that efficiently answers questions that contemplate the type of infrastructure available in educational institutions; for example, what is the current infrastructure in primary education institutions? Considering this infrastructure, classify it by answering questions such as:

- What infrastructure should be considered to apply the evaluated technology? In this infrastructure, what should be considered essential services (water, drainage, and electricity), what are the digital technology concerns (availability of computer equipment or connectivity), and what can safeguard security (signs, evacuation routes, medical office)?

The following questions can help to evaluate the efficiency of the transfer:

- What is the probability of applying the technology successfully in the current infrastructure? What should be the adequacy of the existing infrastructure to increase the probability of successful technology transfer?

Finally, concerning public policy formulation:

- What technologies may have greater applicability in educational facilities? How much infrastructure investment must be put in primary education institutions to reduce technological inequality in the communities?

After analyzing the proposed model, it was possible to generate a set of strategies for implementing and transferring educational technology in the teaching and learning processes. Hence, it was possible to consider Education 4.0 as a tool to scale students' sub-competencies of complex thinking at all educational levels (Tenorio-Sepúlveda et al., 2021). We emphasize that the proposed model can be used at any educational level if the data on the infrastructure of the schools at the middle and higher education levels are available. This represents a significant advance because the model can be a tool to consult before adopting political, administrative, or educational policies.

For this purpose, González Sabater (2011) considered four fundamental aspects for successfully controlling the technological assets to transfer. Their four classifications are tangible, intangible, legal, and adoptive. The tangible aspects relate to physical technology, for example, technical means and technological packages. Intangible aspects are not physically materialized but are essential for their application, whether documented or not. The legal aspects concern industrial or intellectual property. Finally, the adoptive aspects focus on those elements necessary for incorporation into the company, for example, necessity or dependence on external elements, closeness to the technological market, and the necessary technological basis for adoption.

Considering the factors above, this proposal includes tangible, legal, and adoptive factors. It does not consider intangible elements such as the preparation and training of the teaching staff or the resistance in the institutions to apply new educational technologies in the teaching function, among others.

Finally, it is noteworthy that the most significant contributions of the development of this research include: (a) having a quantitative basis for identifying success in implementing educational technology, (b) being able to classify the existing infrastructure, (c) evaluating the degree of infrastructure development, d) determining infrastructure factors for formulating public policies to apply educational technology to improve the teaching-learning process, and e) considering the essential characteristics necessary to transfer this technology. The model does not consider the type of technology transferred because of the enormous complexity of the educational technology transferred.

The impact and transcendence of technology in education: examples from Brazil and Mexico

Educational innovation in Latin America has had limited resonance because it is not only about incorporating technological equipment and its infrastructure for operation, which commonly happens. It is equally important to understand that it has not been possible to measure the pedagogical implications or to have an idea of the substantial impact on education from the innovative processes.

In 2014 Brazil defined specific guidelines in its National Plan of Education. Some critical key points were that education must be universal and equitable and improve education quality. All these guidelines were established in the public administrative management of that year, which opted for democratic management of education and defined objectives and goals that guarantee the right to education. Furthermore, the proposal assumed an objective vision of Information and Communication Technologies (ICT), whose access was recognized by Monteiro (2014) as a human right that must be guaranteed.

In this context, society shapes technology based on interests, needs, or values. For this research, in a comparison between public and private schools, 95 % of students in private schools possessed internet access and supply infrastructure and essential services in their houses; in contrast, only 55 % of students in public schools had access to these services.

Moreover, it is essential to add that inequality exists not only in computer access. It also extends to related services such as access to the internet in public schools. Furthermore, other inequalities result from the lack of reflection regarding learning, where technology helps integrate pedagogical and socio-cultural dimensions. In addition, education should lead to human beings' emancipation when subsequent generations can accomplish inclusivity in project work (Lugo & Kelly, 2010; Monteiro, 2014).

The digital divide is not only present in everyday economic or social activities. This gap exists in education and will endure in marginalized or rural areas. Technology could generate changes to herald a new educational era (Parker et al., 2019). Unfortunately, the lack of massive investment in implementing ICT infrastructure affects educational institutions (Fischman & Haas, 2011).

ICT is critically relevant in education. Accordingly, countries like Mexico have been developing plans to provide the necessary infrastructure for integrating ICT into the primary education system. Likewise, adequate access to the internet and equipment for teachers and students has been pursued. Other goals focus on providing equipment and access to technology to people in marginalized sectors. Studies have revealed an unfavorable or limited impact on coverage in these areas, which was supposed to have been facilitated through innovative and dynamic ICT incorporation (Barriga, 2008).

Chiappe, Mesa and Alvarez (2013) presented results showing that technology alone in education does not provide social equity or inclusion. Moreover, they concluded that technology does not guarantee quality improvement and innovation in the teaching-learning processes. On the other hand, the incursion of ICT has altered the educational paradigms and the ways of teaching, evaluating, and learning. However, we must have a vision of the future and better analyses of the socio-cultural reality thousands of Mexican students experience and the effort they expend to access ICT.

The current challenge is connecting people, empowering communication, and breaking the barriers of time and space, mainly in all physical spaces where education occurs. Also, it is necessary to consider the Knowledge Society as the manager of the educational processes while expanding flexible and reliable information environments, eventually leading to improving the status of marginalized communities, efficient educational environments, and social growth.

Per Glasserman Morales et al. (2016) and Cabero-Almenara and Ruiz-Palmero (2017), it is essential to be aware of the barriers to using ICT, a factor in improving the curricular structure of primary education. First, the technological infrastructure must be assessed. Second, there must be relevant decision-making. Lastly, the technology must support various actors in the educational systems.

Santiago Benítez et al. (2012) presented results regarding inequality and the challenges in education related to technology. The most urgent challenges include the universalization of access to education, the use of ICT, the reduction of the digital divide, and the inequality in different regions of the country. Moreover, Barros (2010) refers to technological infrastructure and critical infrastructure. For example, he defines the latter as all the vital services, or in other cases, the ones required for classes that meet, at least, the minimum levels of quality in education.

Concerning the issue of applying technology, most of the studies mainly analyze the impact of Information Technologies applied in primary education, such as the studies of Domingo Coscollola and Marquès Graells (2011), García-Valcárcel et al. (2014), and Roblizo and Czar (2015). Although these studies discuss the impact of applied technology on the classroom, they do not initially consider the elements necessary for implementing these technologies.

Definition and the types of technology established inside the primary education

Technology is complex because of its amplitude and singularities, which cannot be defined from a unique approach. It is necessary to consider several conceptual aspects to clarify and apply technologies specifically during teaching and learning. Technology is a practicum knowledge derivative from science with an intellectualist vision. Its definition establishes it as a product of applying scientific theories (Brown, 2019; Coccia, 2019; Díaz, 1998). For the instrumentalist, technologies are simple artifacts or tools; he ignores the social, economic, and political interests around their design, development, and control (García Ávila, 2021; Jover Núñez, 2004). Contrary to the instrumentalist vision, the substantive vision establishes technology as not just a source but an environment and way of life (Feenberg, 2000; Raja & Nagasubramani, 2018; Tiwari, 2022).

However, this article focuses on the concept of educational technologies, which is complex because it refers to the integration of people, procedures, ideas, devices, and organizations that lead to the analysis of problems related to the design, implementation, and evaluation of all aspects of the teaching and learning process. Educational technologies must consider the existing resources for learning and be applied considering the diversity of people, materials, devices, techniques, or specifications; likewise, the analysis, design, implementation, and evaluation of solutions must align with the functions of educative development (Saettler, 2004)

Once educative technologies are defined, we can establish that despite the numerous studies on the topic, there needs to be a satisfactory, widespread classification that accounts for the diversity and typology of educational technology. Therefore, we can find an endless categorization that can include its effect on the educative process (Picitelli, 2005), its effect on teaching (Chiappe et al., 2013; Cobo Romaní & Moravec, 2011), and its application in distance education (Dorrego, 2016), among others.

There is a fundamental necessity to provide an integral education with quality and standards of excellence; additionally, it is critical to consider the efficiency criteria for the expenses related to the transfer, assimilation, maintenance, installation, and operation of the required technologies for educational purposes. Therefore, it is vital to consider technology classification according to its application, which helps us identify its purpose (Pabón, 2014).

- Process Technology: Organize methods or procedures, techniques, knowledge, abilities, and experiences applied during the teaching process. Define the stages to transform students into professionals who accomplish the workplace's standards, competencies, abilities, and attitudes and consider the security, impact, and environmental factors.
- Equipment Technology: Organize methods or procedures, techniques or instructions for practice or management of specific equipment, memorization of calculations, equipment or pilot plants for the assimilation of theoretical-practical knowledge, operation manuals, machines, and equipment maintenance, and their components, instrumentation and control, facilities and auxiliary services of the teaching institutions. (Regarding these auxiliary services, they help support the execution of teaching and learning).
- Service Technology: Organize methods or procedures and technique norms, apply knowledge, design and develop educative programs and manuals, define required abilities, and develop experiences so the institutions can provide the service.
- Operation Technologies: Organize methods or procedures (like tutorials, residencies, and professional practices, among others), practice knowledge, process sheets, manuals, abilities, and experiences required for the teaching-learning process of educational institutions. Include defining the type of technology a primary school can require to develop the model based on its various needs and contemplating the specific characteristics of the infrastructure necessary for each type of technology.

Technology management: increasing efficiency in primary education institutions and all educational levels

The above section mainly discussed how technology contributes to achieving equity. According to this, technological implementation in primary and special education institutions comes from understanding social, cultural, and educational contexts. Also, technology offers significant opportunities to train qualified students at all educational levels. Therefore, technology should provide significant support within the teaching-learning process. Managing it should be a priority specific to the needs of each environment. Another important consideration is the dynamic environment of educational institutions. The institutions must efficiently identify the needs and expectations of the new generations of students. Moreover, they need to evaluate the guidelines established by local governments with public policies currently directed mainly at applying technology to reinforce the teaching-learning process. Consequently, it is possible to identify the technology strategy depending on the institutional plans and needs and the public policy proposals which require potentially efficient expenditures for high impact.

To achieve the above, it is first necessary to define technological management as managing technological development and the process in all its stages (Madani, 2019; Migdely et al., 2007; Tas & Yeloglu, 2018). This definition identifies that the development activities are directly related to the intrinsic capacity of the institution to use internally created technologies (i.e., the development of platforms, laboratory improvements, projects carried out by teachers, and virtual teaching-learning platforms, among others) or external ones (e.g., acquisition of computer equipment, specific laboratory equipment, among others).

Alternatively, technology management is viewed as a strategic process (Paniagua, 2007; Sears & Hoetker, 2014; Venter & Grobbelaar, 2022), encompassing five dimensions and the surveillance stages: 1. exploration of the environment to identify opportunities for innovation within the institutions (Bibiana Arango Alzate et al., 2012); 2. identifying the technological elements that improve academic performance within the institutions (Kowang et al., 2022; Salas, 2011); 3. training with the necessary resources for the efficient implementation or operation of the technology (Bell & Pavitt, 1992; Wahyuningsih et al., 2022); 4. implementing all the necessary aspects for the institution's adequate transfer and adoption of the technology (Melo Fiallos et al., 2017); and 5. Learning, meaning acquiring knowledge and experience with innovation and management activities (Garza Toledo, 2006).

After defining the technology management process, it is possible to identify the primary objective of planning and modeling the steps the organizations must follow for adequate assimilation, adoption, and transfer of technology. In other words, it is essential to identify that the technology to acquire covers a need of the institution or the students and is feasible to install and develop. Therefore, models of technology assimilation and transfer become crucial for reducing implementation risks.

Among some of the proposed models in the literature review, we found one for technology transfer management (Klauss, 2000) divided into five fundamental stages: selection, implementation planning, pilot implementation, upscaling, and sustainability. This qualitative model applied a series of questions to identify critical points to consider at each stage of technology transfer management. Notably, in this model, the experience of the implementer and the interpretation of the survey results should be crucial to achieving a positive result in the transfer process. The Klauss model was significantly different from the model presented in this research, in which, from the early stages, it was possible to identify precisely the basic infrastructure necessary for the technology transfer process, and its interpretation depended on a quantitative process of managing a database of the existing infrastructure.

Another model of information technology transfer came from Bottino et al. (1998), who proposed a model of obstacles to innovation in transfer information technologies. The scheme they proposed was a model highlighting four fundamental differences: the nature of the task, the objective of introducing the technology, the human factor, and management. In addition, they proposed six stages for implementing the model —ideation, analysis of the conditions, feasibility, validation, improvement, and dissemination—considering the main actions and stakeholders in each stage. The proposed model significantly differs from the model presented in this paper because it was limited to information technology implemented in schools.

Other models focus on transferring acquired knowledge to apply in the teaching-learning processes. Egan (2020) proposed a model that evaluates the effectiveness of the transfer through a questionnaire that analyzes nine dimensions: teacher experience, program experience, active course learning, self-directed course, formative evaluation, summative evaluation, learning communities and communities of practice, global impact on practice, and demographic information. Likewise, this model quantitatively assesses these components and applies the knowledge acquired in the teaching process. Notably, knowledge is also considered a type of soft technology under the model proposed in this research, although its application is conducted using quantitative evaluation. Finally, there are knowledge and technology transfer models that involve the following six phases for their development: creation, acquisition, connection, transmission, assimilation, and use. These models focus on the existing conditions in university technology assimilation and transfer offices, and their development considers any technology to transfer (Berbegal-Mirabent et al., 2012; Olaya-Escobar et al., 2020). As in the other models, it only contemplates a quantitative analysis of the variables involved.

Another element to identify is classifying the technologies used during the teaching-learning process. Our review identified several approaches, including classifications for classroom media (Bravo Ramos, 2004), distance learning media (Villarruel, 2009), classroom technology, and information technology (Chiappe et al., 2013). The quality of education reflected in students' performance equally considers the contribution of schools to social and economic development. This contribution must be sustainable, allowing the construction of quality education and human and social capital that give more significant opportunities to schools and communities (Aggarwal, 2011; Appels et al., 2022; Cervera Gómez et al., 2008; Yepes, 2004)

More than classification is required to standardize the technologies used in the educational environment. A model's development also needs to focus on the type of technology. This requires knowing the characteristics necessary to adopt, assimilate, or transfer the technology as input elements. The presented elements face challenges not only in the education sector but in the public policies that must be developed for sustainability in the demographics and (even more so) the regional balance and the governments' provisions (Aggarwal, 2011; Arango-Londoño et al., 2022).

Method

A quantitative analysis determined the conditions in which primary education institutions can effectively implement new technology (see Fig. 1), highlighting the need to identify precisely the basic infrastructure conditions required to apply the technology in the first stage correctly. Stages 2 and 3 assess the criticality of the characteristics essential to the operation of the technology and how the infrastructure of the primary education institutions can meet them. Stage 4 establishes the assessment plan to determine the degree of success of the technology implementation, using a quantitative model as described in Fig. 2. Finally, stage 5 considers the formulation of the various policies essential to ensure the correct implementation and use of the technologies based on the analysis of the previous results.

This proposal is quantitative research using experimental designs because:

- The manipulation of the information presented in the database of the Census of Basic and Special Education Schools, Teachers, and Students (CEMABE) considers the existence or not of a particular component of the infrastructure as the independent variable.
- The existence or not of the component in the infrastructure makes it possible to measure the effect within the variable of success probability for the application of technology.
- In this study, the model's validity was tested by evaluating the Mi. Compu.Mx program.

The research questions for this study were:

- What is the probability that a primary education institution can achieve technology transfer?
- What should be the investment or modification to the existing infrastructure to achieve educational and other technology transfer?
- If the intention is to generate a public policy that involves using educational technology to improve education, what should be considered in the current infrastructure for the proposed technology to improve the teaching-learning processes significantly?

Fig. 2 schematically shows the process followed by the proposed method for the technology management system developed in the following steps:

a) In the idea column, the concept of the technology to use is formulated, implying the proposal of technologies and the characteristics necessary for its use; therefore, the researchers must analyze the technical conditions, infrastructure, or other conditions that may interfere with its application.
b) As a second point within the same idea and considering González Sabater (2011) proposal, the model develops the adoption processes, which include infrastructure elements for installation, adoption, and maintenance, all fundamental aspects mentioned by Glasserman Morales et al. (2016). According to CEMABE, the model considers a population of N primary and special education institutions in Mexico, classified into β_i where β_1 is for educational purposes, β_2 means adapted for educational purposes, β_3 indicates light and precarious materials, β_4 represents a mobile school, β_5 without construction, and β_6 unspecified.

Through this classification, it is possible to determine the probability of selecting each using $P_k = N/\beta_i$, with which it is possible to build the Initial Selection (*SI*) vector. Most importantly, it is possible to select the type of institution to which the technology is mainly directed; this is possible thanks to the variable w_i^k, which takes a value of one if this type of institution is selected for the application of the technology and a value of zero in the opposite case. The *SI* vector

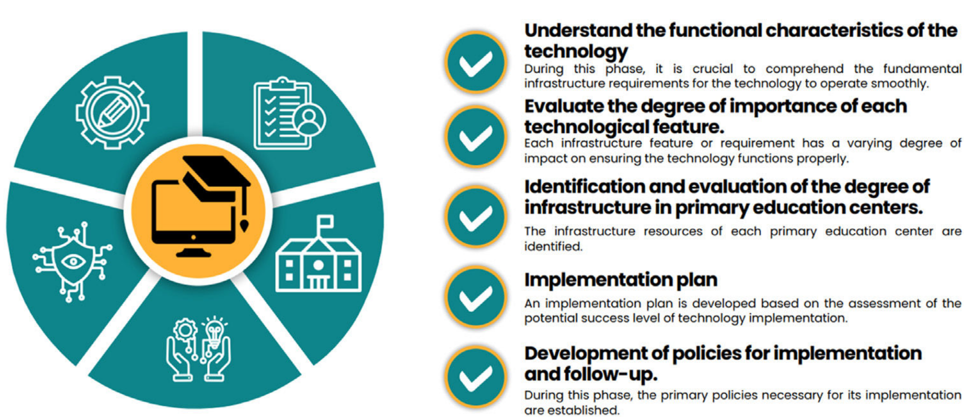

Fig. 1. Stages for the application of the educational transfer model.

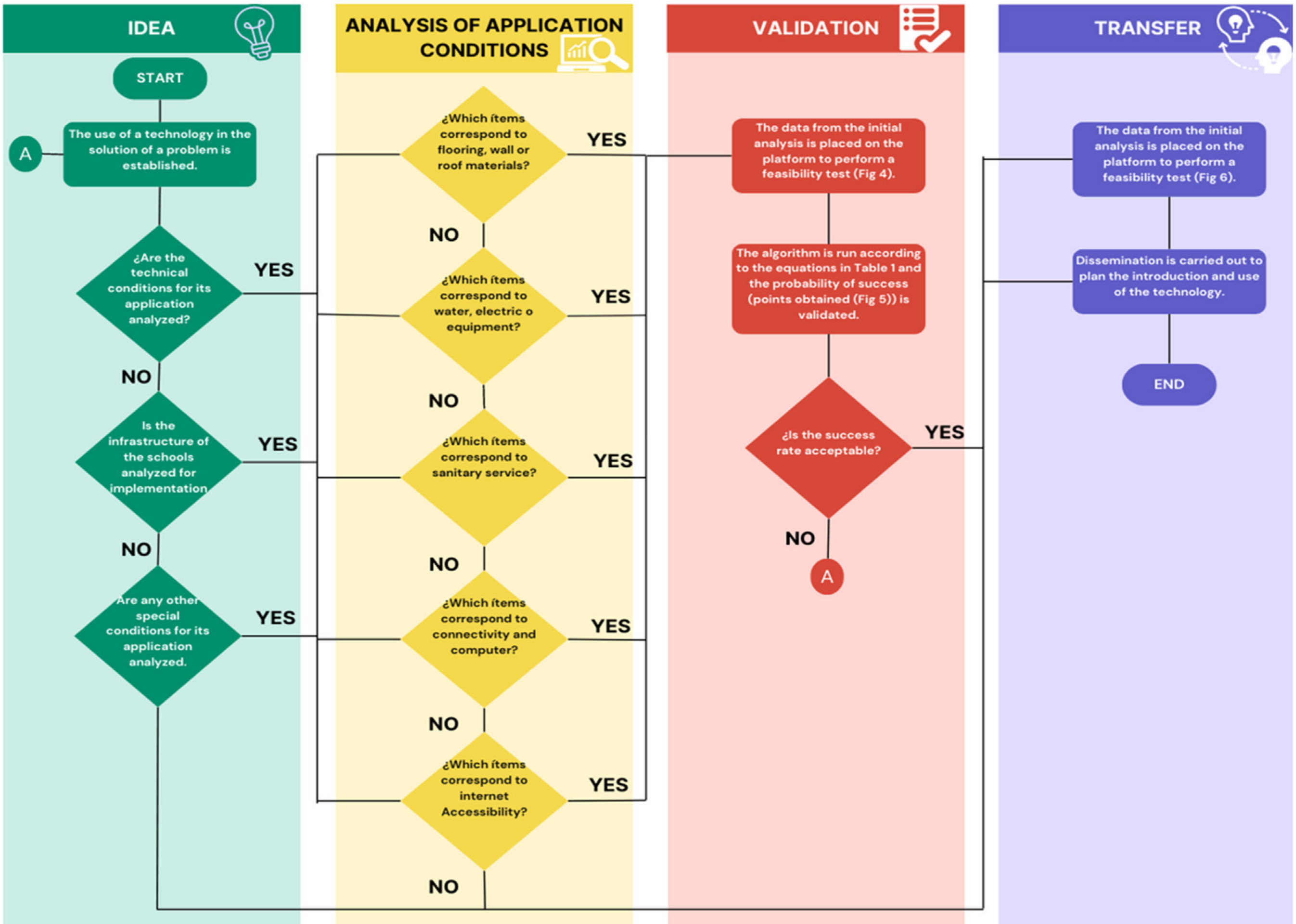

Fig. 2. Block diagram for the application of the technology management mode**.**

is described as follows.

$$SI = \begin{bmatrix} (w_i^k) & (N/\beta_1) \\ (w_i^k) & (N/\beta_1) \\ (w_i^k) & (N/\beta_1) \\ (w_i^k) & (N/\beta_1) \\ (w_i^k) & (N/\beta_1) \\ (w_i^k) & (N/\beta_1) \end{bmatrix} = \begin{bmatrix} w_i^k P_1 \\ w_i^k P_2 \\ w_i^k P_3 \\ w_i^k P_4 \\ w_i^k P_5 \\ w_i^k P_6 \end{bmatrix} \tag{1}$$

Where SI is the initial choice and P_k is the probability of choosing any institution.

The analysis stage of the application conditions considers the elements that comprise the environment of the primary education institutions that are necessary for the application of the technology. Once the vector is finished, SI, the vectors of each element that evaluates the CEMABE within the infrastructure of the primary and special education institutions can be developed, mainly because they are critical to achieving an efficient technological transfer. The institutions' floor materials are an example of developing these vectors, written as:

$$MF = \left[w_i^k MF_1, w_i^k MF_2, \; w_i^k MF_3\right] \tag{2}$$

Where MF is the floor material and $MF_i = N/F_i$. given the probability of N primary and special institutions in Mexico that have the type of floor F_i, F_1 being removable land or materials, F_2 solid concrete, and F_3 representing wood, tile, or another type of covering. On the other side, the binary variable w_i^k, takes the value of one if the type of floor is required for the correct technological acquisition and transfer, and zero if it is not.

a) Subsequently, the conditional elements necessary for applying the technology are identified in the validation stage, as shown in Fig. 2. The validation process is conducted by combining the vectors described in the SI idea (1) and in the analysis of the conditions for its application MF (2), as follows:

$$A_1 = (SI) * (MF) \tag{3}$$

Which can be written as follows:

$$A_1 = \begin{bmatrix} w_i^k P_1 \\ w_i^k P_2 \\ w_i^k P_3 \\ w_i^k P_4 \\ w_i^k P_5 \\ w_i^k P_6 \end{bmatrix} \cdot \left[w_i^k MF_1, w_i^k MF_2, w_i^k MF_3\right] \tag{4}$$

A

$SI \in M_{nx1}(K)$ and $MP \in M_{nx1}(K)$, the product will be defined on how a function $M_{nx1}(K)x \; M_{1xm}(K) \rightarrow \; M_{nxm}(K)$ so that $(SI, \; MF) \rightarrow \; A_1$. Therefore, matrix A_1 can be written as follows:

$\boldsymbol{M_{nx1}(K)x \; M_{1xm}(K) \rightarrow \; M_{nxm}(K)}$

This allows the feasibility test to be completed for subsequent validation of success, as shown in Fig. 3.

Table 1 specifies each vector and describes each element that forms the transfer model's technology.

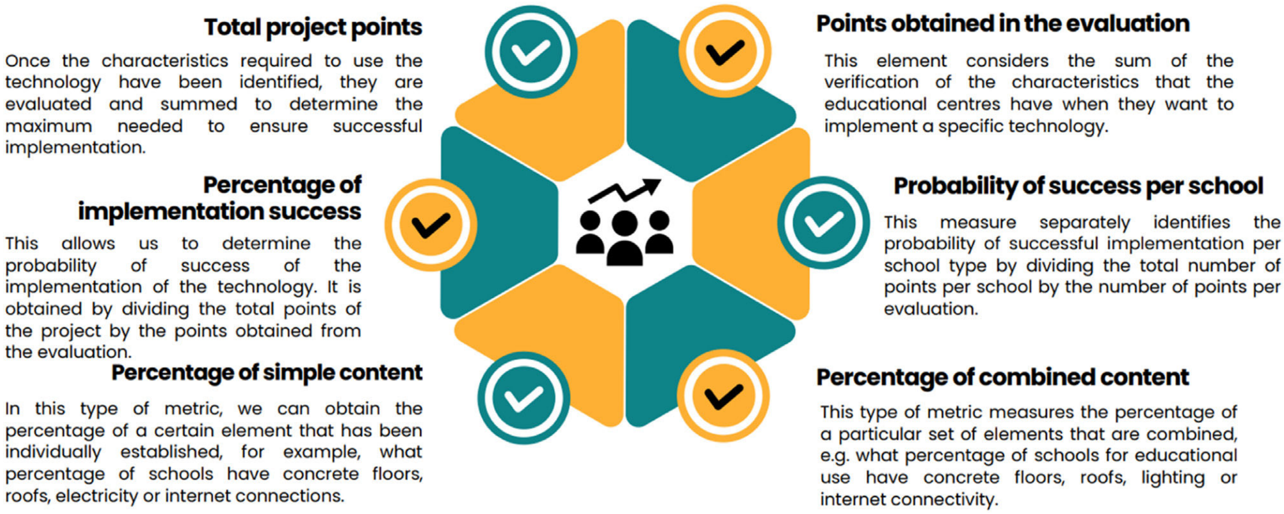

Fig. 3. Metrics for Model Evaluation.

Table 1
Description of the model equations.

Component	Description	
Floor Materials	$MF = [w_i^k MF_1, w_i^k MF_2, w_i^k MF_3]$ $MF_1 = Removable\ land\ or\ material$ $MF_2 = Solid\ concrete$ $MF_3 = Wood,\ tile\ or\ other\ covering$	
Wall Materials	$WM = [w_i^k WM_1, w_i^k WM_2 w_i^k WM_3, w_i^k WM_4, w_i^k WM_5 w_i^k WM_6]$ $WM_1 = Waste\ material$ $WM_2 = Asbestos,\ metal\ or\ cardboard\ sheet$ $WM_3 = Mud,\ reed,\ bamboo\ or\ palm$	 $WM_4 = Wood$ $WM_5 = Adobe$ $WM_6 = Brick,\ block,\ stone,\ quarry,\ cement\ or\ concrete$
Roof Materials	$RM = [w_i^k RM_1, w_i^k RM_2, w_i^k RM_3, w_i^k RM_4, w_i^k RM_5, w_i^k RM_6]$ $RM_1 = Waste\ material\ sheet$ $RM_2 = Asbestos,\ metal\ or\ cardboard$ $RM_3 = Mud,\ reed,\ bamboo\ or\ palm$	 $RM_4 = Beam\ terrace$ $RM_5 = Roof\ tile$ $RM_6 = Concrete\ slab\ or\ joists\ with\ a\ vault$
Water Availability	$WA = [w_i^k WA_1, w_i^k WA_2, w_i^k WA_3, w_i^k WA_4, w_i^k WA_5]$ $WA_1 = Public\ water\ network$ $WA_2 = Pipe\ Truck$ $WA_3 = Well$	 $WA_4 = Hauling\ water$ $WA_5 = Another\ type\ of\ resource\ to\ ensure\ the\ availability\ of\ water$
Electric Availability	$EA = [w_i^k EA_1, w_i^k EA_2, w_i^k EA_3, w_i^k EA_4]$ $EA_1 = Connection\ to\ the\ public\ service$ $EA_2 = Solar\ cells$	 $EA_3 = Electric\ plant$ $EA_4 = Another\ type\ of\ resource\ to\ ensure\ the\ availability\ of\ electricity$
Sanitary Services	$SS = [w_i^k SS_1, w_i^k SS_2, w_i^k SS_3, w_i^k SS_4]$ $SS_1 = Tanks$ $SS_2 = Simple\ pit\ latrine$	 $SS_3 = Restroom$ $SS_4 = Drainage\ system$
Connectivity and Computer Equipment	$CE = [w_i^k CE_1, w_i^k CE_2, w_i^k CE_3]$ $CE_1 = Landline\ telephone$ $CE_1 = Computer\ equipment$ $CE_1 = Internet$	
Equipment Availability	$EV = [w_i^k EV_1, w_i^k EV_2]$ $EV_1 = Blackboard$ $EV_2 = Teaching\ desk$	
Internet Accessibility	$IA = [w_i^k IA_1, w_i^k IA_2]$ $IA_1 = Internet\ access\ to\ students$ $IA_2 = Internet\ accessibility\ to\ teachers$	
Prevention and Security Elements	$PS = [w_i^k PS_1, w_i^k PS_2, w_i^k PS_3, w_i^k PS_4, w_i^k PS_5]$ $PS_1 = Signs\ of\ protection$ $PS_2 = Evacuation\ routes$ $PS_3 = Emergency\ exits$	 $PS_4 = Safety\ zones$ $PS_5 = Nursing\ service$

a) Finally, in the transfer phase, the information from the assessment process is used to develop proposals for improving the infrastructure, systems, or policies necessary for the successful transfer of the technology and its subsequent dissemination and implementation in the established primary education institutions.

Within the proposal, there is a set of indicators for technology adequacy (see Fig. 3): (total points of the project, points obtained in the assessment, percentage of success of the implementation, and probability of success per institution), aimed at providing information on the possible success of technological implementation in the institutions, by comparing the needs of the technical infrastructure with the existing infrastructure in the institutions. Likewise, the model also includes particular evaluation metrics (percentage of simple and combined content) that seek to evaluate, individually or in contrast to another characteristic, its probability of content as a substantial element for the implementation of technology within the institutions.

Discussion

Currently, the Mexican government implements technology in primary education institutions by formulating public policies that rarely consider structural aspects for its efficient operation. Therefore, from the conceptualization of the idea, the necessary conditions for the work of technology in educational institutions are not contemplated nor evaluated, and the possible degree of success or failure that the technological implementation will have been not validated.

Consequently, the present study considers the implementation of technologies, evaluated using an electronic platform that presents a user interface allowing the user to select the necessary infrastructure conditions for the educational technology installation. In this case, we used a tablet. For this purpose, the central panel in the user interface identifies the necessary conditions for the correct transfer and assimilation of the tablet (Fig. 4). It is important to note that not only those elements necessary for the transfer can be selected within the platform, such as the supply of electrical energy and access to the internet by students and teachers. It is also possible to identify if this technology will be used in schools functioning for educational purposes or if in other types of schools, such as mobile schools or those adapted for educational purposes. The identification can extrapolate to all educational levels. In the example, we considered only schools functioning for educational purposes in primary education.

After the initial selection of the parameters, the model determines the probability of success of this technology. The maximum possible score is 3 points; in this case, when running the model within the system, we attained a total of 1.64 points. These points are equivalent to a 55% probability of successful transfer and technological adaptation; the platform displays the results (Fig. 5).

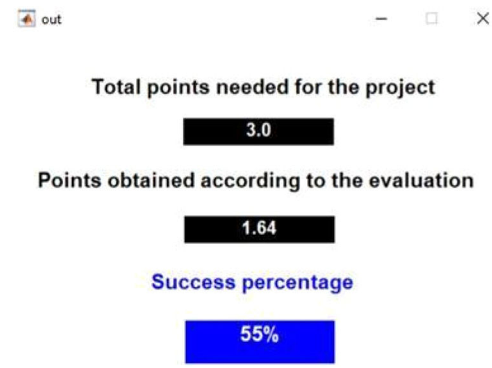

Fig. 5. Probability of success validation.

One of the significant advantages of the platform is that it can send reports on each element evaluated for the technology transfer and its success factor. Fig. 6-a shows that the probability that the school Made for Educational Purposes (MEP) connects to public services is 62%, while it decreases significantly for the other types of schools. On the other hand, the platform sends the individual probability graph of each selected factor. In this case, Fig. 6-b shows only the total probability of the MEP for the connection to public services. Likewise, the results of students' and teachers' accessibility to the internet are presented. These are practical uses of the tablet to reinforce the education received in the classroom. In this factor, the platform displays the data separately regarding the current availability for students (Fig. 6-c) and teachers (Fig. 6-d) in different types of schools, having the highest percentage with 38.96% MEPs for the

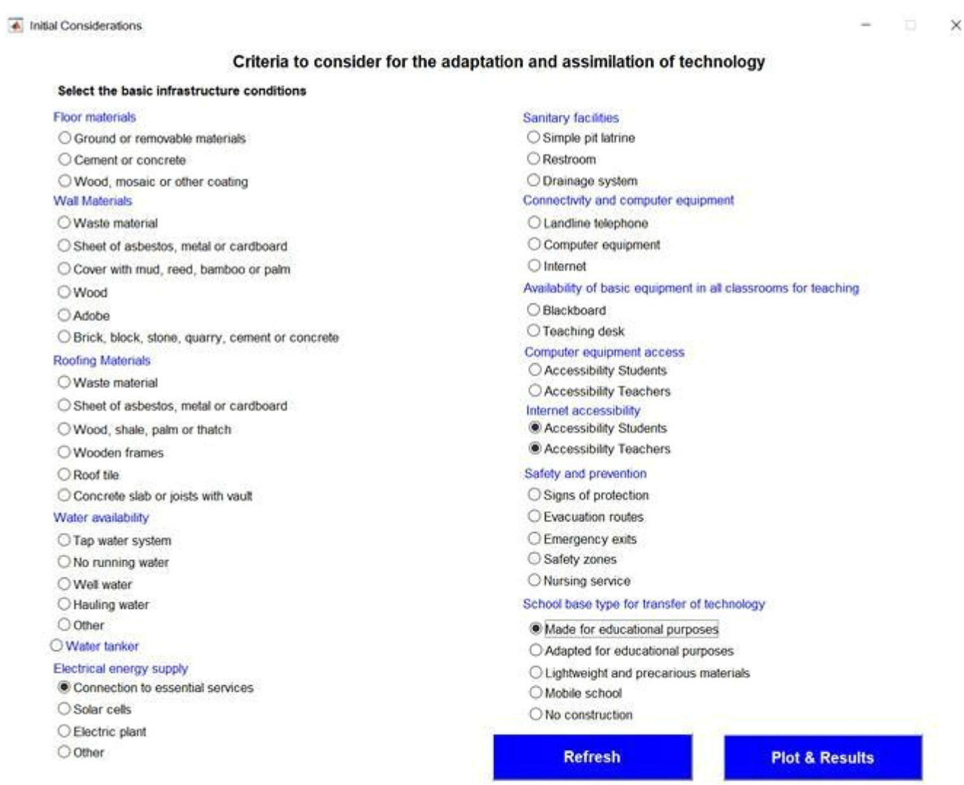

Fig. 4. User interface to establish the characteristics of the technology.

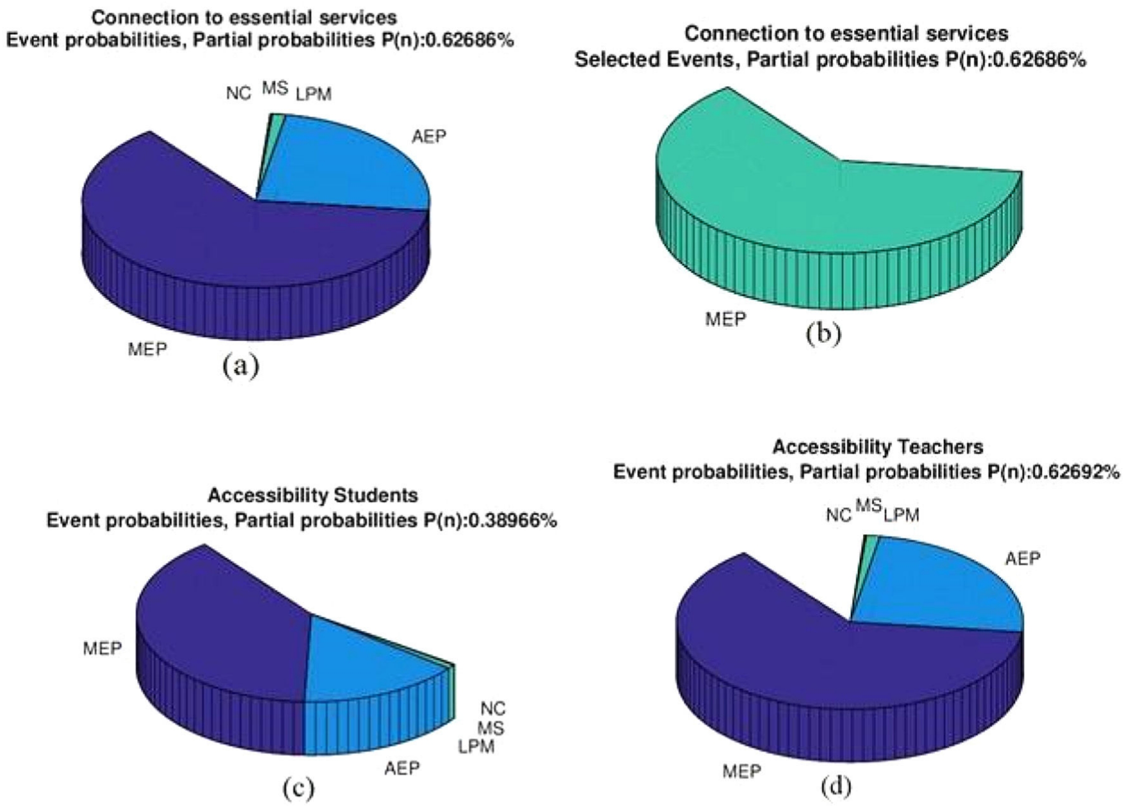

Fig. 6. Partial results of the user interface, MEP (Made for Educational Purposes), AEP (Adapted for Educational Purposes), LPM (Lightweight and Precarious Materials), MS (Mobile School), NC (No construction).

availability of students and 62.69% MEPs for the availability of the teacher.

The platform can graph the data individually, as shown in Fig. 7, for the connection to the public services of the MEPs for students and teachers (see figures (a) and (b)). These elements are presented individually for internet availability for students and professors in the MEP. It is possible to observe that the biggest challenge for the proper transfer and assimilation of the tablets within the primary education institutions of Mexico lies in whether these can connect to the internet and are available for students and teachers.

Considering the above, it is possible to establish that for a policy or program seeking to implement electronic equipment within the teaching-learning process to be successful, the following activities must improve or take place:

- Limit the use of the program to primary education institutions functioning for educational purposes because they present the best suitability for this kind of equipment.
- At the same time, education administrators must consider the investment in infrastructure to have an internet connection that allows the use of tablets.
- The internet service should consider connecting students' devices first and teachers later.

Lastly, this management model for technology allows practical assessment of the implications of implementing technologies in schools, becoming effective for decision-making.

Implications for theory and practice

Theoretical implications

There are three theoretical implications: a) Through this research, it has been possible to observe the importance of having mixed models of qualitative and quantitative analysis, which may contribute to

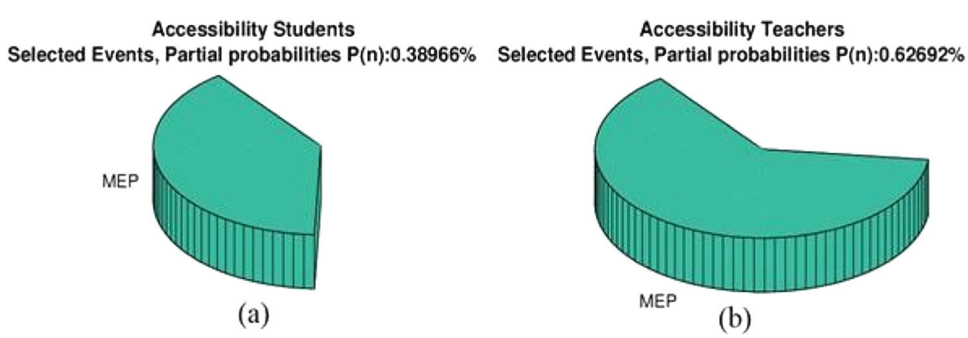

Fig. 7. Individual results of the user interface.

assessing the implementation and technology transfer, thus generating strategies based on specific analyses of the organization's environment to ensure achievement of the transfer process; b) The research demonstrated the need for official and reliable information to design technology management systems that use databases to support the technology validation phases; and c)The research highlighted the introduction of correlation and probability functions to support the planning for the improvement of technology transfer systems.

Implications for practice

This research reviewed various models of technology transfer in education to identify qualitative (Bottino et al., 1998; Klauss, 2000) and quantitative (Berbegal-Mirabent et al., 2012; Egan, 2020) models. In this regard, one of the observed challenges is the importance of having a mixed-type model that combines the analysis of quantitative data obtained through the measurement of different parameters and metrics and qualitative analysis, which covers aspects associated with the actors involved in the process. Thus, it is possible to conduct analyses that, on the one hand, determine the type of infrastructure and resources available to achieve technology transfer and, on the other hand, deepen analyses of the stakeholders' actions, such as the training of teachers who must use these technological resources. Hence, creating new mixed evaluation models that consider both qualitative and quantitative reviews is essential to develop transfer models.

The consequences of using technology transfer models in education are significant because they make it easier for students to learn and develop skills with the right technological resources in educational settings. So, applying technology transfer models can facilitate access to cutting-edge technologies and creative educational materials, enhancing instructional quality and efficacy. Also, it can assist students in acquiring technology and digital competencies beneficial to their performance. Yet, several important potential social and cultural implications need to be thoroughly investigated in the future, for instance, a knowledge and access gap among students from various socioeconomic backgrounds (Parker et al., 2019; Saettler, 2004). The relationship between teachers and students and the teacher's role as a learning facilitator may also be negatively impacted over time (Melo Fiallos et al., 2017). Therefore, a well-planned approach must consider the possible effects of technology transfer in education and critically assess its suitability for use in particular contexts (Lugo & Kelly, 2010).

Limitations and future research

There may be some substantial drawbacks to the technology transfer model focused on primary education, specifically, three relevant limitations in the methodology described in this work. First, it is crucial to note that the model is quantitative, which means it is based solely on numerical and statistical facts that indicate the likelihood that the technology transfer will succeed. This model does not consider qualitative variables like cultural and social factors that may influence this process. As a result, the model's users must consider these qualitative factors simultaneously because they may impact the transfer's probability of success. Since the model does not consider the educational process's complexity or the learning process's multidimensionality, it may also have other significant limitations, such as reductionist or simplistic decision-making. Last, the need for adequate and current data is a persistent risk that could impair the validity and accuracy of technology transfer models and their use in particular educational contexts.

Future studies replicating this model could examine higher education. It is feasible to conduct research studies to examine the correlations between the requirement for infrastructure and resources, the quality of instruction, and the successful application of technology transfer. Research that examines the elements that affect the acceptance and efficient application of technologies in higher education, such as teacher preparation, accessibility and equity in technology use, and the assessment and measurement of the effects and efficacy of technology transfer models, can also be incorporated.

Conclusions

Undoubtedly, the challenges to education in Mexico are diverse; among these, primary public education faces the most significant ones. A prominent difficulty is the necessity of generating public policies that result in programs to advance quality education significantly through technology that triggers students' knowledge and skills development. The application of technology in primary education can be a powerful ally in teaching-learning but with significant limitations. Technological success depends considerably on the conditions previously established for its correct assimilation, adoption, and function.

As described above, the development model and the user interface can generate scenarios necessary for policies regarding the acquisition, assimilation, transference, and adoption of educational technology. In the analyzed case, tablets in the teaching-learning process had a 55% chance of being effective, given the conditions that most schools face; and only 66% had a supply of electrical energy adequate to charge the devices. Furthermore, the limited availability of the internet for students, being only about 39%, significantly reduces the probability of success of the tablets, so before the acquisition of such devices, other policies must emanate from the platform.

Considering the above, the proper acquisition, assimilation, transfer, and adoption of tablets in Mexico's primary, special education, secondary, and higher education institutions can occur to ensure the program's success. Henceforth, the platform must allow a quick evaluation of any technology desired in the educational process, creating policies for optimizing resources and ensuring success in its introduction.

With this background and the vertiginous dynamics and shifts worldwide, the possibility of determining the technology that can be used successfully in schools or institutions allows the implementation of educational strategies drawn from Education 4.0. Additionally, we will be able to propose new educational strategies articulating the technology for developing sub-competencies of complex thinking in students to face the digital era or any emergent situation. Also, governments should foster open access and open science for students and people in general, which is vital for technological transformation in schools and institutions.

Finally, but not less importantly, we discussed different definitions of the "classification of technology" from an educational approach. We could not find a specific tendency among authors that provide more details about its definition. We found that they agree about the classification proposal, which should proceed, suiting the impact of its intrinsic characteristics. Concerning the model proposed in this paper, it is most important benefit is operating without bias toward any technology the model should use, whether soft, hard, or mixed. The only thing that matters to the model is the characteristics of the technology adaptation and its ability to transcend organizations.

Acknowledgment

The authors acknowledge the financial and technical support of Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

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