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Educational software for teaching mathematics to first grade primary school children with hearing impairment in .NET framework

Software educativo para la enseñanza de las matemáticas en niños de primer grado de primaria con discapacidad auditiva en .NET framework

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Abstract

This article presents the results obtained from the development of an educational software made as a desktop application in .NET Framework for first grade children with hearing impairment to strengthen the learning of mathematics through the use of Mexican Sign Language; the research contributes to the SDG 5 Sustainable Development Goal of quality education and SDG 10 Reducing inequalities, sustainable development goals proposed by the United Nations. The agile software development methodology XP Extreme Programming was followed for project management, it was implemented with .NET Framework technologies, IDE Visual Studio and C# programming language, which allowed to obtain a quality software easy to implement and maintain.

Educational software, XP, .NET Framework, Visual Studio, C#

Resumen

En este artículo se presentan los resultados obtenidos del desarrollo de un software educativo realizado como una aplicación de escritorio en .NET Framework para que los niños de primer año de primaria con discapacidad auditiva fortalezcan el aprendizaje de las matemáticas a través del uso de la Lengua de Señas Mexicana; la investigación contribuye al ODS 5 Objetivo del desarrollo sustentable de educación de calidad y ODS 10 Reducción de desigualdades, objetivos de desarrollo sostenibles propuestos por las Naciones Unidas. Se siguió la metodología ágil de desarrollo de software XP Programación Extrema para la administración del proyecto, se implementó con las tecnologías .NET Framework, IDE Visual Studio y el lenguaje de programación C#, lo que permitió obtener un software de calidad fácil de implementar y mantener.

Software educativo, XP, .NET Framework, Visual Studio, C#

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Introduction

The article presents the implementation process of an educational software designed and implemented under the requirements established by the Alberto Jiménez Valderrábano Elementary School, which allows to strengthen the mathematics teaching-learning process in first grade children with hearing impairment and contribute to an equitable and inclusive education by reducing educational inequality in this exposed sector of the population.

The importance of the article is in the first place, the solution strategy that was proposed to support a vulnerable population, children with hearing impairment; according to the World Health Organization in 2020, more than 1,000 million people live on our planet with some type of disability, about 15% of the world's population; Of this population, almost 190 million have problems in their functioning and require assistance from third parties, another outstanding data is that of the Population and Housing Census 2020, which indicates that in our country Mexico has 6,179,890 people with some type of disability, representing 4. 9 % of the total population of the country. (National Institute of Statistics, Geography and Informatics [INEGI], 2020). Of these 22% are hearing impaired, despite the use of hearing aids, a situation that leaves them at a disadvantage in their social and educational environment mainly; secondly, applying an agile methodology called XP Extreme Programming for its simplicity and practicality to manage the project, allowed to obtain a quality software, completed on time and under the specifications of the educational institution linked.

Researchers' projects that serve as a reference for the proposed research were identified, and the following were found:

Researchers Fernandez and Fernandez et al. (2020) present a software solution with a user-centered design and usability techniques for hearing impaired people, basically children, to interact with the system and allow them to exercise communication activities.

Díaz Vásquez et al. (2021) propose a tactile technology to be used in the education of students with special impairments such as deafness in two educational institutions in Ecuador in order to improve teaching at school and at home.

The conference "Inclusive learning: school performance in arithmetic with the mobile application for the deaf" by Rodríguez Peña et al. (2019) propose a mobile application to improve school performance in mathematics, specifically in the area of arithmetic in deaf elementary school students.

Herrera Rivas (2022) in his Thesis "Aplicación del Modelo de Desarrollo Evolutivo en un Software Educativo" proposes visual didactic material that consolidates the teaching-learning process in mathematics for deaf students in basic education.

Del Pezo Izaguirre et al. (2021) identify various Teaching-Learning (TL) methodologies that when combined with mobile applications and Extended Reality (XR) technology have a positive impact on the academic performance of hearing impaired students.

Skultety et al. (2023) propose a framework that offers a way to develop a teaching practice to support mathematics teacher preparation within existing content and methods courses based on the current landscape of mathematics learning.

Alasim (2023) investigated Saudi Arabian primary school teachers' knowledge of strategies for teaching components of reading to students with hearing difficulties.

XP Extreme Programming

Extreme Programming, known as XP, is an agile methodology with the objective of responding quickly and with quality to customer requirements and achieving customer satisfaction. It considers that customer requirements change throughout the process and that it is necessary to adapt in an agile way. In Kent Beck's words, it is "a light, low-risk, flexible, predictable, scientific and fun process". It is based on four interdependent values: Simplicity, communication, feedback and courage.

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It proposes very short and fast process cycles, with immediate unit testing and continuous integration. The versions developed are functional, iterative and incremental until all customer requirements are met (Gómez Palomo and Moraleda Gil, 2020). Figure 1 shows the phases of XP, its iterative, simple and agile behavior, as well as the activities performed in each phase of the methodology.

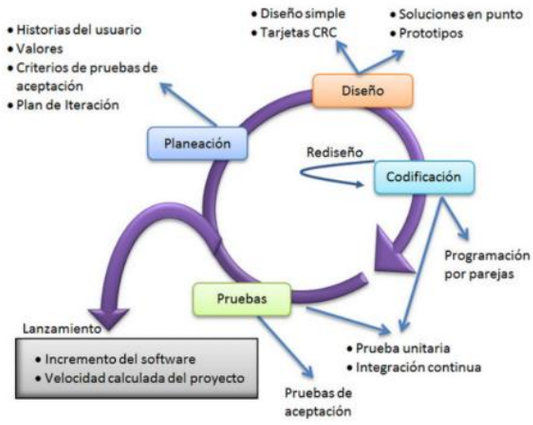

Figure 1 Extreme Programming according to Beck
Source: Gómez Palomo and Moraleda Gil (2020)

.NET Framework

It is a platform for the development of software of all types from desktop programs to web applications, it provides different services to developers' applications without being limited to a programming language or operating system. It consists of two components: the Common Language Runtime (CLR), considered as the execution engine, and the .NET Framework class library, which provides developers with reusable and tested code.

The services provided by the .NET Framework to running applications are as follows:

Memory management. The CLR component is in charge of obtaining the maximum usefulness of the memory.

Common type system. The type system defines the basic types common to the different language.

Extensive type library. An easily accessible type library is provided to programmers.

Development frameworks and technologies. It offers a diversity of libraries for application development areas.

Language interoperability. The language compilers that use .NET generate a Common Intermediate Language (CIL) that at the same time is compiled at runtime through the CLR, making routines written in one language accessible to other languages.

Version compatibility. All applications developed in previous versions can be executed without problems in later versions.

Parallel execution. The resolution of conflicts between versions is offered, and several versions of the CLR are installed on the computer without generating problems.

Multi-version support: Developers can create diverse class libraries that operate on .NET Framework platforms compatible with the .NET Standard version (Microsoft Learn, 2023).

Visual studio

It is an IDE for .NET developers on Windows that allows you to compile rich and attractive cross-platform applications for Windows, Mac, Linux, iOS and Android operating systems. It compiles applications with a wide variety of technologies.

Visual Studio's features allow you to increase productivity, improve code quality, and provide agility to the development team (Microsoft, 2023).

C#

It is a modern, object-based, type-safe programming language. C# allows developers to create many types of type-safe applications.

C# programs run on .NET, with the two components described: the CLR and the class library. The CLR runtime engine is Microsoft's implementation of the Common Language Infrastructure (CLI). CLI is the foundation for creating execution and development environments in which languages and libraries work seamlessly (Microsoft Learn, 2023).

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Mexican sign language

Mexican Sign Language is the language of the deaf community in Mexico, and is formed by a set of signs articulated with the hands and accompanied by facial expressions and body movements, the vocabulary of the language and its grammar are complex and vast.

There are variations in Mexican Sign Language according to the geographical location of the country, and it differs with languages by word order and in the use of verbs. (Government of Mexico, 2019).

The problems that the research aims to address are the difficulties encountered by teachers from the first grade of primary school in teaching mathematics to students with hearing disabilities, as well as the lack of interactive teaching materials implemented in public educational institutions that adhere to the educational programs of the Ministry of Public Education, in Mexican Sign Language. As a result, a desktop application will be obtained, for the Windows operating system, implemented under the XP methodology and the C# programming language in .NET Framework, easy to implement and maintain.

The article is organized as follows: first section is the introduction where the problem to be addressed and the proposed solution are described, as a second section you will find the software development methodology that was implemented for the development of educational software for teaching mathematics in first grade elementary school children with hearing impairment developed in .NET Framework. In the third section you will find the results where the images of the developed application are shown. In the fourth section you will find the acknowledgements and funding sources, the conclusions of the work done and finally the references.

Methodology

The software development methodology applied was XP Extreme Programming. Table 1 lists the activities performed in the phases of the methodology:

Activities of the Planning phase:	• Collection of User Stories • Define the Plan of Deliveries and Iterations • Weekly follow-up meetings
Activities of the Design phase:	• Simple design • CRC cards • Weekly meetings
Activities of the Coding phase:	• Pair programming • Sequential and continuous integration • Recode if necessary • Weekly meetings
Activities of the Testing phase:	• Unit Testing • Acceptance testing • Weekly meetings

Table 1 Planning of activities by phase
Source: Own elaboration

Planning and design

In order to specify the software requirements, the XP methodology proposes dynamic and flexible cards; the following is a simplified list of Educational Software User Stories and Figure 2 shows as an example the HU2 User Story, the card describes its behavior, users involved, estimation of its development, among others.

HU1: Organize the learning of hearing impaired children through sections called Blocks indicated in the book of Mathematics for the First Grade of Primary School provided by the Ministry of Public Education.

HU2: To contain in each block a set of visual and interactive activities that promote the learning of hearing impaired children.

HU3: Instruct each activity with images and short sentences in Spanish, reinforced with Mexican Sign Language.

HU4: Contain for each block a final evaluation of the hearing impaired child's learning.

HU5: Contain feedback in Mexican Sign Language in all activities.

USER HISTORY	
NUMBER: HU2	**USER:** Student with hearing impairment, teacher of the group
NAME OF STORY: Block Activities	
BUSINESS PRIORITY: High (High, Medium, Low)	**DEVELOPMENTAL RISK:** Medium (High, Medium, Low)
ESTIMATED POINTS: 4 weeks	**ITERATION ASSIGNED:** 2
RESPONSIBLE DEVELOPER: Carmen Jeannette Sampayo Rodríguez, Blanca Areli González Martínez	
DESCRIPTION: Contain in each block a set of visual and interactive activities that promote learning for hearing impaired children.	
REMARKS: Only defined users (hearing impaired students) will have access to the educational software functionalities.	

Figure 2 User History Card HU2
Source: Own elaboration

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Figure 3 presents the System Delivery Plan and Iterations, considering that four weeks of work were required for each iteration.

USER STORIES	ITERATION	PRIORITY	EFFORT	DATE START	DATE FINAL
HU1	1	High	2	05/12/2022	13/01/2023
HU2	2,3,4	High	2	16/01/2023	21/04/2023
HU3	2,3,4	High	2	16/01/2023	21/04/2023
HU4	2,3,4	Medium	2	16/01/2023	21/04/2023
HU5	2,3,4	Medium	2	16/01/2023	21/04/2023

Figure 3 Delivery Plan and Iterations
Source: Own elaboration

For the simple design of the application that would allow understanding the general structure of the Educational Software, the Draw.io tool was used, where each graphical user interface was created as it would be perceived by the hearing impaired children, considering at all times a simple and intuitive structure.

The free primary level textbooks are inclusive by considering gender equality and interculturality, however, they were not designed for children with hearing or visual disabilities.

Achieving an intelligible design is to facilitate, complement and strengthen the learning of the hearing impaired child by being fed back with images and Mexican Sign Language at all times.

Figure 4 (a) shows the Home view combining Spanish statements with Mexican Sign Language and (b) visualizes the three Blocks in which the content of the Educational Software is organized, as indicated by the Ministry of Education in the book Mathematics, First Grade.

a)

b)

Figure 4 a) Startup Interface Design b) Draw.io Educational Software Blocks Menu Interface Design
Source: Own elaboration

Figure 5 shows the organization of the interface of the Block's learning activities, with statements in Spanish and action buttons reinforced with images alluding to the topic.

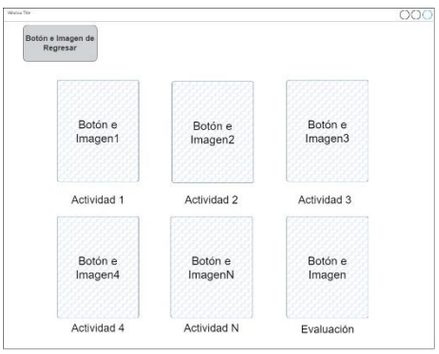

Figure 5 Interface Design of Activities per Block in draw.io
Source: Own elaboration

Figure 6 (a) shows the design of the interface when the child with a disability chooses an activity, instructions in Spanish with their respective translation into Mexican Sign Language, the execution of the exercise, and (b) shows the feedback on the performance of the exercise.

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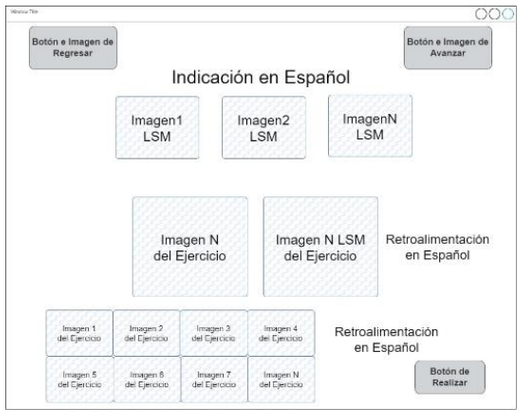
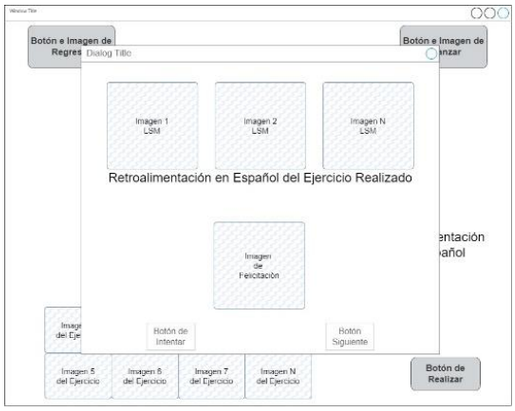


a)



b)

Figure 6 a) Interface Design of the Activity. b) Interface Design with feedback of results in draw.io
Source: Own elaboration

Software architecture is a description of the subsystems and relationships that make up a system. The architecture used was monolithic, distinguished by the fact that it is easy for the development team to initiate the project and get it up and running, also because it is a stand-alone application, which allows it to operate independently of other applications, and the processing is done locally because it does not require consuming distributed processes to complete a task. A typical monolithic application uses an independent layered design for the user interface, application logic and data access (Blancarte Iturralde, 2023).

Figure 7 presents the monolithic software architecture represented in a deployment diagram, with a layered design used for the implementation of the Educational Software.

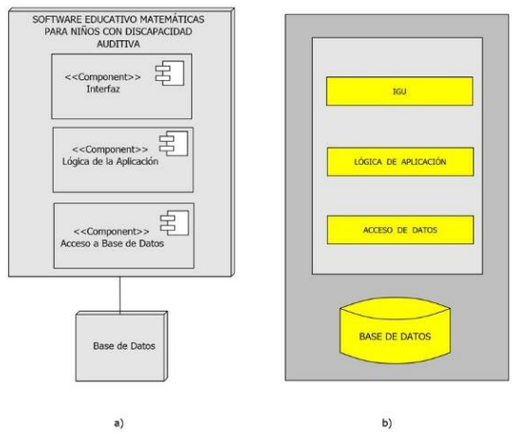


Figure 7 a) System Deployment Diagram b) System Layer Design in Dia
Source: Own elaboration

CRC cards facilitate the identification of classes that will intervene in the application. Designing these cards is appropriate to improve the understanding of the design. For the project, 4 CRC cards were designed with the Classes: Block, Activity, Evaluation and Student with Hearing Impairment as shown in Figure 8.

BLOCK	
Responsibility	**Collaboration**
Save Block information	
Verify Activities	Activity
Verify Evaluations	Evaluation

ACTIVITY	
Responsibility	**Collaboration**
Saving activity information	
Verify activity information	
List activities	
Verify the blocks	Block

EVALUATION	
Responsibility	**Collaboration**
Saving evaluation information	
Verify activity information	Activity
Verify evaluation information	
Report evaluation performance	Student with HI

STUDENT WITH HI	
Responsibility	**Collaboration**
Save HI Student Information	
Verify HI Student Information	
Verify activity information	Activity
Verify performance information from evaluations	Evaluation

Figure 8 System CRC cards
Source: Own elaboration

Coding and Testing

Organizing the solution as a project, in order to have a well-defined structure is important for educational software. A good practice is to structure in a tree structure through directories or folders, which in turn will contain files for easy access and categorized storage.

Visual Studio, when starting a project, contains all the files that are compiled into an executable file. These files may include source code, icons, images, data files, etc. It also contains compiler configuration and other configuration files that might be needed (Microsoft, 2023).

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Figure 9 shows the graphical representation of the Educational Software file and folder hierarchy, in which the Visual Studio Solution Explorer nests related files to help programmers organize them and make them easier to locate.

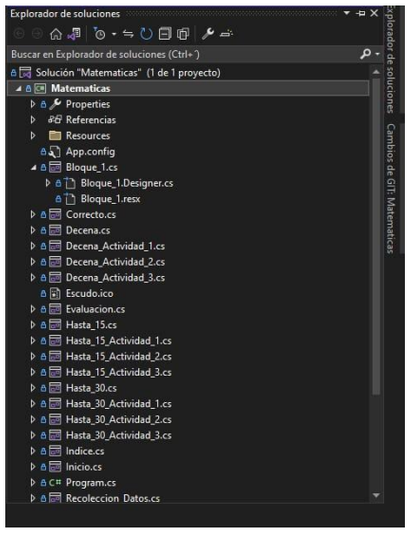

Figure 9 Organization of folders and files of the Educational Software
Source: Own elaboration

Figure 10 shows the coding that was developed for the Block 1 activity set form.

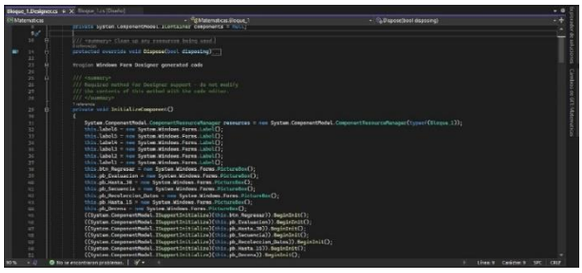

Figura 10 Code of the form Index of Activities of Block 1
Source: Own elaboration

For the Testing phase, Unit and Acceptance Test Cases were designed to verify the correct functioning of the educational software and guarantee a quality product.

Figure 11 shows the template used for the User Story Test Case CP_HU4 Final evaluation of Block 1.

TEST CASE	
CODE: CP_HU4	**USER HISTORY NUMBER**: HU4
USER STORY:	
Final evaluation of Block No. 1	
CONDITIONS OF EXECUTION:	
The USER (hearing impaired student) is required to be logged in and to have completed all the activities in block No. 1 to be evaluated	
INPUT/EXECUTION STEPS:	
The USER (hearing impaired student) will have to enter the block he/she wants to make his/her evaluation, for the case No. 1. The USER (hearing impaired student) will have to select the Evaluation image. The USER (hearing impaired student) will have to perform the final activities. The SYSTEM will indicate the status of the evaluation with a brief statement and Mexican Sign Language. The USER (hearing impaired student) will be able to repeat the evaluation if desired.	
EXPECTED RESULT:	
Evaluation of Block 1 completed and saved.	
EVALUATION OF THE TEST:	
The functional type test is: Satisfactory / Partially Satisfactory / Not Satisfactory.	

Figure 11 Test Case CP_HU4, designed for execution in Iteration 2
Source: Own elaboration

This is how to achieve a project that will allow you to follow up and maintain it in the best way and achieve a much simpler implementation of new functionalities.

Results

The following are the interfaces of the Educational Software for teaching mathematics to hearing impaired children in the first grade of primary school developed in .NET with the IDE Visual Studio under the C# programming language.

Figure 12 shows the Home view of the Educational Software and the following one shows the three blocks in which the learning of the subject Mathematics for children in first grade of primary school is organized according to the free educational book authorized by the Ministry of Public Education (Secretaría de Educación Pública, 2019).

Figure 12 Startup Views and Block Organization of the Educational Software
Source: Own elaboration

Figure 13 shows the view with the index of the set of learning activities that the hearing impaired child could choose, in this case, the activities of Block 1 and their corresponding evaluation are exemplified. Images taken from the First Grade Mathematics book authorized by the Ministry of Public Education and the signs from the book Manos con Voz (Serafín de Fleischmann and González Pérez, 2011) were included.

Figure 13 View of the Index of Activities of Block 1.
Source: Own elaboration

In Figure 14, if the activity "Up to 15" is chosen, the exercise that the child with a disability must solve is presented. All the activities have a brief instruction in Spanish that is reinforced with Mexican Sign Language, and at the end the exercise is fed back in the same way.

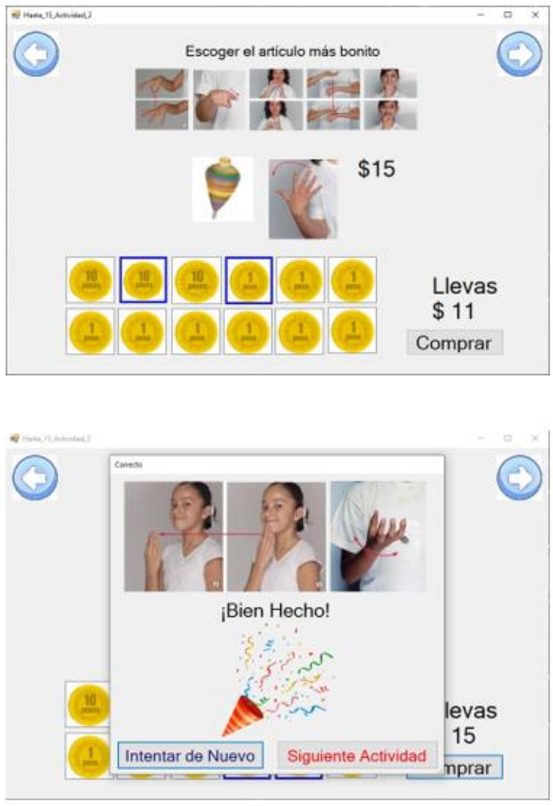

Figure 14 Views of the Activity "Up to 15" of the Educational Software
Source: Own elaboration

Acknowledgments

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Conclusions

In conclusion, it was possible to implement a sustainable and local educational software for the Windows operating system following the agile methodology XP Extreme Programming, the C# programming language, the Visual Studio IDE in .NET Framework, resulting in a friendly desktop application and easy maintenance to promote new features in the future.

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One of the future improvements is that this application works on mobile devices so that it can be consulted by its users at any time and place desired.

References

Alasim, K.N. (2023). Knowledge of Strategies to Teach Reading Components among Teachers of Hard of Hearing Students, *The Journal of Deaf Studies and Deaf Education*, 28(2), 201–210, https://doi.org/10.1093/deafed/enac047

Blancarte Iturralde O. J. (2023). *Arquitectura Monolítico. Software Architect*. https://reactiveprogramming.io/blog/es/estilos-arquitectonicos/monolitico

Del Pezo Izaguirre, E., Abásolo, M. J., y Collazos, C. A. (2021). Metodologías educativas para niños sordos apoyadas en tecnología móvil y realidad extendida: un análisis sistemático de literatura. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, 16(4), 410-418, https://doi.org/10.1109/rita.2021.3135202

Díaz Vásquez, R. A., Acosta Espinoza, J. L., y Checa Cabrera, M. A. (2021). Software educativo basado en tecnología de pantalla táctil para la enseñanza en estudiantes con capacidades especiales. *Revista Conrado*, 17(81), 396-404. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1990-86442021000400396&lng=es&tlng=en

Fernández y Fernández, C. A., Aguilar Cisneros, J., y Cruz González, G. (2020). Hacia un sistema de software basado en IHC para el apoyo de niños con capacidades auditivas diferentes. *ReCIBE Revista electrónica de Computación, Informática, Biomédica y Electrónica*, 9(1), 1-12. https://doi.org/10.32870/recibe.v9i1.168

Gobierno de México (10 de junio de 2019). *Día nacional de la Lengua de Señas Mexicana (LSM)*.https://www.gob.mx/conadis/articulos/dia-nacional-de-la-lengua-de-senas-mexicana-lsm-203888?idiom=es

Gómez Palomo, S.R. y Moraleda Gil, E.A. (2020). *Aproximación a la Ingeniería de Software*. Centro de Estudios Ramón Areces SA.

Herrera Rivas, R. (2022). *Aplicación del Modelo de Desarrollo Evolutivo en un Software Educativo*. [Tesis de Licenciatura, Instituto Tecnológico de Minatitlán] Repositorio Institucional del Tecnológico Nacional de México. https://rinacional.tecnm.mx/jspui/handle/TecNM/5029

Instituto Nacional de Estadística, Geografía e Informática. (2020). *Información de México para niños*. https://cuentame.inegi.org.mx/poblacion/discapacidad.aspx

Microsoft (2023). *Codifique más rápido, trabaje de manera más inteligente*. Visual Studio. https://visualstudio.microsoft.com/es/vs/

Microsoft Learn. (10 de febrero de 2023). *Introducción a .NET Framework*. .NET Framework. https://learn.microsoft.com/es-mx/dotnet/framework/get-started/

Microsoft Learn. (15 de febrero de 2023). *Paseo por el Lenguaje C#*. Documentación de C#. https://learn.microsoft.com/es-es/dotnet/csharp/tour-of-csharp/

Rodríguez Peña, J. J., Ayala Jiménez, G. G., Barragán López, J. F., García Ramírez, M.A., Escudero Nahón, A., López Torrijo M. y Vicario Solórzano, C. M. (9-10 de octubre de 2019). *Aprendizaje inclusivo: Rendimiento escolar en aritmética con la aplicación móvil para sordos* [Sesión de Conferencia]. CIVINEDU 2019 3rd International Virtual Conference on Educational Research and Innovation. http://www.civinedu.org/wp-content/uploads/2019/12/CIVINEDU2019.pdf

Secretaría de Educación Pública. (2019) *Matemáticas Primer Grado*. Dirección General de Materiales Educativos.

Serafín de Fleischmann, M.E. y González Pérez, R. (2011). *Manos con Voz, Diccionario de Lengua de Señas Mexicana*. Consejo Nacional para prevenir la discriminación.

ISSN 2523-0360

Skultety, L., Saclarides, E. S., Bajwa, N. P., Brown, K., Poetzel, A., & Gerardo, J. M. (2023). Making sense of elementary pre-service teachers' mathematical wounds: A proposed framework for practice. *International Electronic Journal of Mathematics Education*, 18(2), em0738. https://doi.org/10.29333/iejme/13170.

ISSN 2523-0360