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ESPECIAL

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GAMIFICACIÓN PARA ASISTIR PROCESOS EN INGENIERÍA DE SOFTWARE: UN ESTUDIO TERCIARIO

GAMIFICATION to assist processes in software ENGINEERING:A Tertiary study

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RESUMEN

En las últimas décadas la estrategia de la gamificación ha impactado en la mejora de los procesos tanto en la industria del software como en las actividades de formación de recursos humanos en Ingeniería de Software. El propósito de este trabajo es analizar mediante un estudio terciario las revisiones sistemáticas que han sido publicadas en el período de tiempo del 2015 al 2024, con la intención de comprender como se ha abordado la temática del impacto del uso de técnicas de gamificación como estrategia en la IS. La metodología utilizada para el mapeo sistemático se integra por las siguientes fases: (a) Planeación del estudio, (b) Ejecución del estudio y (c) Reporte de resultados. Como resultado del mapeo sistemático se encontraron 10 estudios secundarios, en la mayoría de los artículos informa-ron que están orientados a fomentar habilidades blandas en las personas: la motivación, mejorar la participación, mayor rendimiento y colaboración entre los miembros de los equipos, por otro lado, se observó que los elementos de gamificación más utilizados son los puntos, las insignias y las tablas de clasificación. A pesar de que los estudios secundarios han evidenciado resultados positivos de la gamificación en la IS, se requiere realizar más investigación empírica para consolidar específicamente la aplicación de la gamificación en IS en el contexto del trabajo en equipo para optimizar la colaboración y consolidación de los equipos de desarrollo software.

PALABRAS CLAVE

Gamificación, Ingeniería de Software, Mapeo Sistemático.

ABSTRACT

In recent decades, the gamification strategy has impacted the improvement of processes both in the software industry and in human resources training activities in Software Engineering. (SE). The purpose of this work is to analyze, through a tertiary study, the systematic reviews that have been published from 2015 to 2024, with the intention of understanding how the impact of using gamification techniques as a strategy in SE has been addressed. The methodology used for the systematic mapping is composed of the following phases: (a) Study planning, (b) Study execution, and (c) Reporting of results. As a result of the systematic mapping, 10 secondary studies were found; most of the articles reported that they are aimed at fostering soft skills in individuals, such as motivation, improving participation, increasing performance, and enhancing collaboration among team members, on the other hand, it was observed that the most commonly used gamification elements are points, badges, and leaderboards. Although secondary studies have shown positive results of gamification in SE, more empirical research is needed to specifically consolidate the application of gamification in SE in the context of teamwork to optimize collaboration and the cohesion of software development teams.

KEYWORDS

Gamification, Software Engineering, Systematic Mapping.

1. INTRODUCCIÓN

El término de gamificación se refiere, de manera general, a la aplicación de elementos de juego en contexto que no son de juego, mejorando la experiencia y compromiso de los participantes (Korn, Funk, & Schmidt, 2015). En los últimos años, se ha evidenciado un despliegue progresivo de las estrategias de gamificación más allá de su ámbito tradicional, incursionando con éxito en campos tan diversos como la educación, la salud, el marketing, y en el mismo sentido, la Ingeniería de Software (IS) no ha sido la excepción. Esta expansión ha propiciado oportunidades significativas para su integración en el desarrollo de productos y la optimización de procesos dentro de la IS (Herranz, Colomo-Palacios, & de Amescua Seco, 2015), (Osborne O'Hagan, Coleman, & O'Connor, 2014), así como también dichas técnicas de gamificación han sido empleadas para realizar actividades establecidas en el desarrollo de software en el ámbito académico (Latulipe, Long, & Seminario, 2015).

La integración de técnicas de gamificación para la formación de equipos de trabajo ha sido un desafío pendiente hasta el momento; aunque se ha observado la utilidad de estas técnicas en la identificación de perfiles de los miembros del equipo de desarrollo (Jurado, Fernández, & Collazos, 2015). Estudios han puesto de manifiesto la aplicación exitosa de técnicas de gamificación en la ejecución de actividades por parte de equipos de trabajo en diferentes entornos, tanto en ámbitos empresariales como en académicos; dichos estudios han revelado el impacto positivo de las actividades gamificadas en la participación de los involucrados.

A pesar de estos avances, la creación de recomendaciones prácticas para mejorar el rendimiento de los equipos de trabajo mediante la gamificación sigue siendo un desafío considerable (Dutra, Prikladnicki, & França, 2015). Esta tarea no solo requiere un entendimiento profundo de las dinámicas de equipo, sino también la adaptación de estrategias gamificadas que estimulen la colaboración, la productividad y el compromiso sin imponer dificultades adicionales.

La IS es una disciplina innovadora que se dedica a resolver problemas complejos mediante la construcción de soluciones basadas en conocimiento, involucrando equipos multidisciplinarios (Ghezzi & Mandrioli, 2005). Aunque el trabajo en equipo ha sido crucial en la ingeniería tradicional, ha ganado aún más relevancia con el modelo educativo CDIO (Muñoz Venegas, Martínez Araneda, Cárdenas Oviedo, & Cea Echeverría, 2017), que destaca estas habilidades.

Aunque las habilidades de trabajo en equipo se afianzan en la práctica profesional, es esencial cultivar las bases durante la educación universitaria. Este énfasis en las habilidades de equipo se refleja tanto en la industria, que busca profesionales con estas capacidades fundamentales (Bowen, Alvaro, Mejia, & Saffi, 2004), como en el diseño curricular de la IS. La formación de habilidades básicas en estudiantes de nivel licenciatura se ha convertido en un pilar esencial en la educación de programas con el perfil de Ingeniero de Software.

En el presente estudio terciario, se utiliza el Mapeo Sistemático como metodología para seleccionar y caracterizar estudios secundarios en la ventana de tiempo del 2015 al 2024, los cuales utilicen las técnicas de gamificación, tanto para los procesos en el ámbito educativo, como con los relacionados con la industria del software.

2. MARCO TEÓRICO

2.1 Ingeniería de software

La IS es la disciplina que se ocupa de todos los aspectos del desarrollo de software, incluyendo las actividades de ingeniería de requisitos, modelos de procesos, modelos y técnicas de estimación entre las actividades más importantes (Sommerville, 2005). La IS ofrece enfoques sólidos para aumentar las posibilidades de que los objetivos de negocio se cumplan en términos de tiempo, calidad y funcionalidad. Las organizaciones se enfrentan al reto de llevar a cabo sus actividades de forma productiva, con calidad y el cumplimiento de la planificación estratégica. Por lo tanto, el uso de un enfoque adecuado en el desarrollo de software para la obtención de requisitos, la estimación, el desarrollo y el control es esencial para las organizaciones (Ramos, Noriega, Laínez, & Durango, 2017).

2.1.1 Ciclo de vida del software

El término ciclo de vida del software se ha definido para implicar las diferentes etapas (o fases) a lo largo de las cuales un software evoluciona desde una solicitud inicial del cliente hasta un software completamente desarrollado y finalmente hasta una etapa en la que ya no es útil para ningún usuario y luego se descarta. Las fases principales por las que pasa el desarrollo software son: análisis y especificación de requisitos, diseño, codificación, pruebas, y mantenimiento. Finalmente, el software se retira cuando los usuarios ya no lo encuentran útil debido a razones tales como un cambio en el escenario comercial, la disponibilidad de un nuevo software con características y funcionamiento mejorados, cambios en las plataformas informáticas, etc. Esto forma la esencia del ciclo de vida de cada software (Mall, 2018).

2.2 Gamificación

Como ocurre con cualquier campo nuevo y en expansión, no existe una definición única y unificada sobre gamificación, aunque la mayoría incorpora un conjunto de aspectos ampliamente aceptados. Se han producido intentos de gamificar actividades en sectores muy diferentes como la industria y la educación, En el mundo empresarial, las empresas buscan aumentar el compromiso de los clientes y los trabajadores, mientras que el contexto de la educación, la gamificación se utiliza no sólo como herramienta de aprendizaje para diferentes campos y materias, sino también para el desarrollo de actitudes, comportamientos colaborativos y el aprendizaje de manera autónoma. La gamificación es el uso de elementos de diseño de juegos en contextos ajenos al juego según (Deterding, Dixon, Khaled, & Nacke, 2011). Por su parte (K. M. J. T. D. Kapp, 2012) define el enfoque de gamificación como la aplicación de mecánicas de juego en áreas que no son propiamente juego para estimular y motivar tanto la competencia como la cooperación entre los jugadores.

2.2.1 Tipos de Gamificación

Existen dos tipos de estrategias instruccionales basadas en gamificación según (K. M. Kapp, 2013):

La gamificación estructural es la aplicación de elementos del juego para motivar al alumno a través del contenido sin alterar ni cambiar el contenido. El contenido no se vuelve parecido a un juego, pero la estructura alrededor del contenido sí. Los elementos más comunes en este tipo de gamificación son los puntos, insignias, logros y niveles. Este tipo también suele tener una tabla de clasificación y métodos para seguir el progreso del aprendizaje, así como un componente social donde los alumnos pueden compartir logros con otros alumnos y presumir de lo que han logrado. Aunque es posible agregar elementos de historia, personajes y otros elementos del juego a la gamificación estructural, el contenido no cambia para convertirse en un juego.

La gamificación del contenido es la aplicación de elementos y pensamiento del juego para modificar el contenido y hacerlo más parecido a un juego. Por ejemplo, agregar elementos de la historia a un curso de cumplimiento o comenzar un curso con un desafío en lugar de una lista de objetivos son ambos métodos de gamificación de contenido. Agregar estos elementos hace que el contenido se parezca más a un juego, pero no lo convierte en un juego. Simplemente proporciona contexto o actividades que se utilizan en los juegos y las agrega al contenido que se enseña.

2.2.2 Elementos de Gamificación

(Werbach & Hunter, 2013) como resultado una lista de verificación de diseño para obtener una gamificación efectiva, dicha lista es conocida como marco 6D: definir objetivos de negocio, delinear los comportamientos objetivo, describir a tus jugadores, diseñar bucles de actividad, ¡No olvidar la diversión! e implementar las herramientas adecuadas. En el paso 4 llamado “Diseñar bucles de actividad” se crean los principales aspectos de juego de su sistema.

Este marco involucra tres tipos de elementos, denominados Dinámica, Mecánica y Componentes los cuales se encuentran clasificados en una jerarquía. Las dinámicas Son los aspectos generales del sistema gamificado qué se debe considerar y cómo gestionarlo. Las mecánicas son los procesos que provocan el desarrollo del juego y los componentes son las instancias específicas de las dinámicas y mecánicas (Werbach & Hunter, 2015).

2.3 Estudios previos

Se llevó a cabo una revisión de estudios terciarios previos que abordaran la temática de la gamificación como estrategia aplicada en la ingeniería de Software para determinar oportunidades de aspectos que aún no se han investigado, en los cuales centraremos nuestro estudio. A continuación, se presentan dos estudios terciarios seleccionados:
Gamification in Software Engineering: A Tertiary Study (García-Mireles & Morales-Trujillo, 2020) El objetivo de este estudio se centra en comprender cómo se ha abordado la gamificación, y su impacto en la Ingeniería de Software, por lo que se realizó un mapeo sistemático en el cual se seleccionaron 12 estudios secundarios, como resultado de las búsquedas en las bases de datos: (1) Web of Science, (2) IEEE Xplore, y (3) ACM Digital Library. Como resultado se obtuvo que la mayoría de los artículos destacan el uso de puntos, insignias y tablas de clasificación como elementos de juego en el proceso de ingeniería de software, métodos y herramientas de ingeniería de software y gestión de ingeniería de software.

Gamification in Software Engineering Education: a Tertiary Study (Tonhão et al., 2023) Este artículo presenta un estudio terciario que investiga la aplicación de la gamificación en la educación en Ingeniería de Software. Se realizó en respuesta a revisiones sistemáticas de literatura y mapeos quedando seleccionados 10 estudios secundarios como resultado de las búsquedas en las bases de datos: (1) Web of Science, (2) IEEE Xplore, (3) ACM Digital Library, (4) Scopus y (5) Springer. Entre los hallazgos que revela este estudio terciario se encuentra que las áreas de Ingeniería de Software gamificadas con mayor frecuencia son las pruebas de software y la calidad del software, siendo la competencia y la cooperación los elementos de gamificación más utilizados. Por otra parte, la mayoría de los estudios se centran en la gamificación estructura. Los resultados demuestran el potencial de la gamificación para mejorar el compromiso y la motivación de los estudiantes durante todo el proceso de aprendizaje de Ingeniería de Software, al mismo tiempo que impacta otros aspectos como la mejora del desempeño, el desarrollo de habilidades y el fomento de buenas prácticas.

Aunque estos estudios terciarios informaron un impacto positivo de la gamificación, se requiere más investigación. En otras palabras, las investigaciones actuales se centran en la viabilidad de utilizar la gamificación en diferentes áreas del Ingeniería de Software; sin embargo, existe la necesidad de investigar el contexto de aplicación, determinar que habilidades desarrolla en las personas, definir cuáles son los esquemas de trabajo en los que se usan las técnicas de gamificación para llevar a cabo una investigación más sólida.

3. METODOLOGÍA

Con el objetivo de identificar, evaluar e interpretar los resultados de la investigación disponible de acuerdo al tema abordado en el presente estudio, el uso de las técnicas de gamificación como estrategia en la ingeniería de software, se utilizó como referencia metodológica la propuesta en (Keele, 2007), con adaptaciones de la guía propuesta en (Petersen, Feldt, Mujtaba, & Mattsson, 2008); Los estudios seleccionados y analizados son estudios secundarios, pero por otro lado nuestro estudio corresponde a estudio terciario, en el cual se proporciona una visión integral de la información recopilada (Nurdiani, Börstler, Fricker, & Software, 2016). Las fases de que consta dicha metodología están delimitadas de la siguiente manera: Planeación de la Revisión, Ejecución del Estudio y Reporte de Resultados.

4. PLANEACIÓN

En fase de Planeación se construyen las preguntas de investigación que guiarán el estudio, así como el objetivo que persigue cada una de las preguntas, se seleccionan las Bases de Batos con las que se va a trabajar y se plantea una estrategia de búsqueda a través de términos y cadena que estarán relacionadas mediante operadores lógicos, así como los criterios de inclusión y exclusión que servirán para reducir la selección de los estudios encontrados.

4.1 Preguntas de investigación

Con el objetivo de identificar el entorno donde se ha aplicado la gamificación como estrategia en la ingeniería de software, así como determinar hacia quienes están orientados los estudios realizados en el período de tiempo (2015-2024) y que tipo de habilidades desarrollan, se establecieron un conjunto de Preguntas de Investigación (PI) para guiar este mapeo sistemático.

- PI-1. ¿Cuál es la distribución de las publicaciones por año en la ventada de tiempo del 2015 al 2024?
- PI-2. ¿En cuáles contextos han sido aplicadas las estrategias de gamificación en la ingeniería de software?
- PI-3. ¿Qué tipos de estudios secundarios han sido utilizados en las investigaciones publicadas en la ventada de tiempo del 2015 al 2024?
- PI-4. ¿Sobre qué tipo de habilidades han sido orientadas las estrategias de gamificación en la ingeniería de software?
- PI-5. ¿Bajo qué esquemas de trabajo han sido aplicadas las estrategias de gamificación en la ingeniería de software?
- PI-6. ¿Qué elementos de gamificación han sido utilizados como estrategia en la ingeniería de software?

4.2 Selección de fuentes y estrategias de búsqueda de estudios secundarios

Con el objetivo de identificar los estudios secundarios para el mapeo sistemático en una investigación orientada a la ingeniería de software, se seleccionaron las siguientes bases de datos del área de computación: *ACM Digital Library, IEEE Xplore, ScienceDirect, Springer Link, Taylor & Francis*, y como repositorio se utilizó *Google Scholar.*

4.3 Creación de la cadena de búsqueda

Se identificaron palabras las claves de la investigación relacionadas con gamificación, estudios secundarios y las áreas del conocimiento de la Ingeniería de Software. Las palabras claves fueron combinadas mediante el uso de operadores lógicos AND y OR, que permitieron vincular los términos principales y/o alternativos, respectivamente. Como resultado se obtuvo la siguiente cadena de búsqueda:

> *("gamification" OR "gamify" OR "gamified" OR "gamifying") AND ("software engineering" OR "software process" OR "software requirements" OR "software design" OR "development" OR "programming" OR "coding" OR "software testing" OR "software verification" OR "software validation" OR "software maintenance" OR "software implementation" OR "software configuration management" OR "software engineering management" OR "software configuration" OR "software quality") AND ("literature review " OR "systematic review" OR "survey" OR "mapping" OR "systematic mapping studies")*

4.4 Criterios de inclusión y de exclusión

Con el propósito seleccionar un conjunto de estudios secundarios pertinentes al tema y en particular a las PI, se definieron un conjunto de criterios de inclusión y exclusión. A continuación, en la Tabla 1 se encuentran los criterios considerados por los investigadores para realizar la selección de estudios secundarios:

Criterios de inclusión (CI)		Criterios de exclusión (CE)	
CI-1	Estudios empíricos vinculados con la temática de estrategias de gamificación aplicadas en la ingeniería de software	**CE-1**	Estudios duplicados; se contabilizará el estudio en la Base de Datos original.
CI-2	Estudios empíricos publicados en revistas especializadas.	**CE-2**	Artículos incrementales en torno a un mismo estudio, se seleccionará el reporte más completo.
CI-3	Estudios publicados en la ventana de tiempo del 2015 al 2024.		
CI-4	Estudios publicados en idioma inglés.		

Tabla 1. Criterios de inclusión y exclusión.

5. EJECUCIÓN DEL ESTUDIO

De acuerdo con lo planteado en la fase de Planeación, se configuraron las cadenas de búsqueda según con las características de los manejadores en cada Base de Datos del repositorio que fue seleccionado, y haciendo uso de dichas cadenas resultantes, se realizó el proceso de búsqueda; con el resultado del proceso de búsqueda se aplicaron los criterios de inclusión y exclusión, en dicho orden, obteniendo en cada etapa, el número de estudios que se muestra en la Tabla 2. Como resultado del proceso se seleccionaron un total de 10 estudios secundarios.

Bases de Datos	Búsqueda (Cadena)	Criterios de Inclusión	Criterios de Exclusión
IEEE Xplore	120	0	0
ACM Digital Library	396	0	0
Springer Link	35	0	0
Taylor & Francis	163	1	1
ScienceDirect	130	4	4
Google Scholar	218,000	5	5

Tabla 2. Número de estudios obtenidos de acuerdo con la etapa del proceso.

Base de Datos	Cita	Título	# EP
Taylor & Francis	(Darejeh & Salim, 2016)	Gamification Solutions to Enhance Software User Engagement—A Systematic Review.	78
ScienceDirect	(Pedreira, García, Brisaboa, Piattini, & technology, 2015)	Gamification in software engineering–A systematic mapping.	29
	(Alhammad, Moreno, & Software, 2018)	Gamification in software engineering education: A systematic mapping.	132
	(de Paula Porto, de Jesus, Ferrari, Fabbri, & Software, 2021)	Initiatives and challenges of using gamification in software engineering: A Systematic Mapping	103
	(Souza et al., 2018)	A systematic mapping study on game-related methods for software engineering education.	156
Google Scholar	(Barreto & França, 2021)	Gamification in Software Engineering: A literature Review.	130
	(de Jesus, Ferrari, de Paula Porto, & Fabbri, 2018)	Gamification in software testing: A characterization study.	15
	(Hernández, Muñoz, Mejia, & Peña, 2016)	Gamification in software engineering teamworks: A systematic literature review.	31
	(Cursino, Ferreira, Lencastre, Fagundes, & Pimentel, 2018)	Gamification in requirements engineering: a systematic review.	8
	(Gari, Walia, & Radermacher, 2018)	Gamification in computer science education: A systematic literature review	16

Tabla 3. Estudios Secundarios Seleccionados por Base de Datos.

En la Tabla 3, se citan los trabajos analizados en el estudio, provenientes de las Bases de Datos consultadas donde se encontraron estudios secundarios pertinentes; con el propósito de identificar la magnitud de la investigación realizada, la cuarta columna presenta el número de estudios primarios analizados en cada uno de los estudios secundarios seleccionados, por tanto, los 10 estudios secundarios integran el análisis de 698 estudios primarios.

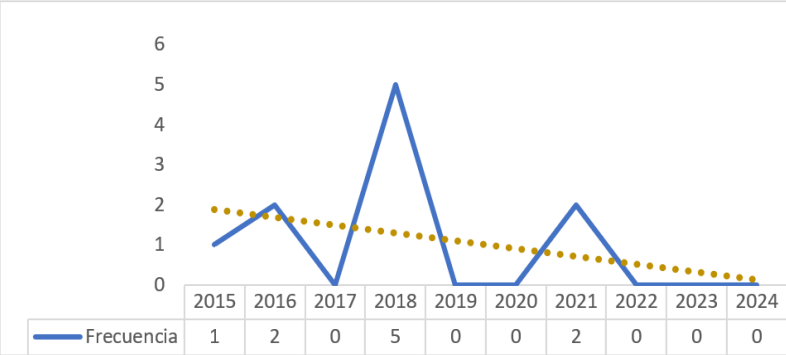
6. RESULTADOS

En esta sección los 10 estudios secundarios seleccionados —5 publicados en revistas y los otros 5 en conferencias— fueron revisados exhaustivamente para dar respuesta a la PI planteadas y llevar a cabo el presente estudio terciario.

PI-1. ¿Cuál es la distribución de las publicaciones por año en la ventada de tiempo del 2015 al 2024?

La distribución que se ilustra en la Figura 1 presenta que hay una baja frecuencia de publicaciones de estudios secundarios a lo largo de la ventana de tiempo del 2015 al 2024. El año 2018 destaca como una anomalía en esta tendencia, con un pico significativo de cinco publicaciones. Por lo que,

aunque en la mayoría de los años la frecuencia de publicaciones es baja o nula, hubo un año en el que la actividad de publicación fue notablemente mayor. En general, podemos observar cómo hay pocos y a la vez una tendencia de decreciente de estudios secundarios publicados en torno a la temática del uso de la gamificación como estrategia en la IS.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Frecuencia	1	2	0	5	0	0	2	0	0	0

Figura 1. Distribución de publicaciones en la ventana de tiempo del 2015 al 2024.

PI-2. ¿En cuáles contextos han sido aplicadas las estrategias de gamificación en la ingeniería de software?

Las estrategias de gamificación aplicadas en la IS en los estudios secundarios seleccionados se desarrollan en tres contextos: Educación, Industria y Mixto (Educación - Industria). En la Figura 2 podemos observar que 4 de los estudios (Darejeh & Salim, 2016), (de Jesus, Ferrari, de Paula Porto, & Fabbri, 2018), (Hernández, Muñoz, Mejia, & Peña, 2016), (Pedreira, García, Brisaboa, Piattini, & technology, 2015) se centran tanto en la Industria como en la Educación en la IS. Por otro lado, se encontró que 3 estudios secundarios se desarrollaron en el contexto de la Educación (Alhammad, Moreno, & Software, 2018), (Souza et al., 2018), (Gari, Walia, & Radermacher, 2018) y otros 3 estudios en el contexto de la Industria (de Paula Porto, de Jesus, Ferrari, Fabbri, & Software, 2021), (Barreto & França, 2021), (Cursino, Ferreira, Lencastre, Fagundes, & Pimentel, 2018).

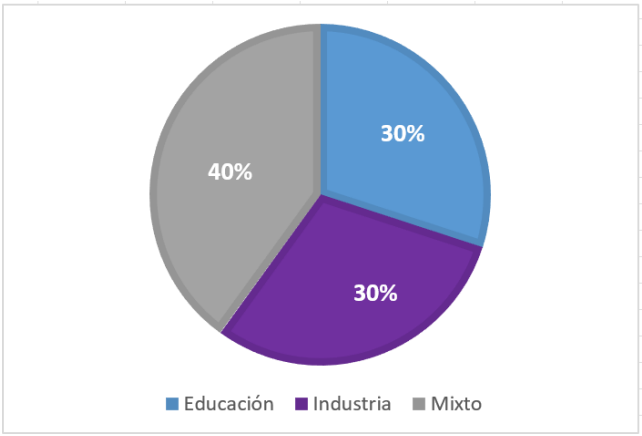


Figura 2. Contextos donde se ha aplicado la estrategia de gamificación en la ingeniería de software.

PI-3. ¿Qué tipos de estudios secundarios han sido utilizados en las investigaciones publicadas en la ventada de tiempo del 2015 al 2024?

Los tipos de estudio secundario que han sido utilizados en las investigaciones publicadas en la ventada de tiempo del 2015 al 2024 arrojan resultados homogéneos, ya que, en total 5 estudios son Revisiones Sistemáticas de Literatura (RSL) y los otros 5 estudios restantes pertenecen a Estudios de Mapeos Sistemáticos (EMS). Con el objetivo de poder observar la distribución de los tipos de estudio secundario en el periodo de análisis, se representaron los datos obtenidos en la Figura 3. Se puede visualizar que en 2015 solo se publicaron EMS y en 2016 solo RSM, mientras que en 2018 y 2021 las publicaciones son de ambos tipos; cabe destacar que no se identificaron estudios secundarios en todos los años de la ventana de tiempo analizada, y que 2018 fue el año con mayor producción de estudios secundarios (5).

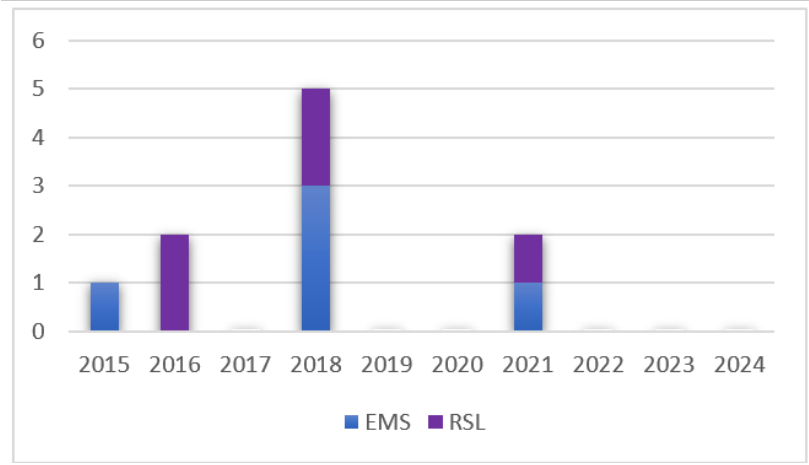


Figura 3. Estudios secundarios seleccionados entre 2015 y 2024 según su tipo.

PI-4. ¿Sobre qué tipo de habilidades han sido orientadas las estrategias de gamificación en la ingeniería de software?

Las Soft-Skills o por su nombre en español habilidades blandas, son usualmente relacionadas con comportamientos, interacción con los demás y patrones de personalidad; esta idea se refiere a las capacidades aprendidas y utilizables para la adaptabilidad en los diferentes contextos en los que pueda relacionarse el sujeto, tales como su ambiente escolar o de empleabilidad (Cobo & Moravec, 2011); de modo que son aquellas habilidades, que permiten poner en práctica valores que contribuyen a que la persona se desarrolle adecuadamente en los distintos ámbitos de acción (Buxarrais Estrada, 2013). En el 90 % de los estudios secundarios obtenidos las estrategias de gamificación en la IS fueron orientadas a desarrollar habilidades blandas, ya que la gamificación promueve este tipo de habilidades en las personas. En la información que se obtuvo al analizar los estudios secundarios se hallaron que las habilidades que más se desarrollaron fueron: la motivación, mayor participación, mejor rendimiento y desempeño de las personas y mayor colaboración entre los miembros de los equipos. El otro 10 % pertenece al estudio desarrollado por Souza et al. (2018), el cual además de desarrollar habilidades blandas también desarrolló habilidades técnicas (Hard Skills), las cuales son aquel conocimiento técnico que ha adquirido un profesional mediante la experiencia académico-profesional obtenida, que le permiten tener un mejor desarrollo en sus actividades u oficios en el ámbito laboral para la ejecución de procesos de producción (Villacorte Sánchez & Pérez Aranguren, 2022). En dicho estudio las habilidades técnicas que se buscan desarrollar en los estudiantes de ingeniería de software fueron el uso más frecuente de herramientas específicas, la adquisición del hábito de aplicar técnicas definidas, adquirir hábitos para el desarrollo de software profesional e inducir habilidades o prácticas de IS.

PI-5. ¿Bajo qué esquemas de trabajo han sido aplicadas las estrategias de gamificación en la ingeniería de software?

La mayoría de los artículos (8 estudios secundarios) reportan que los procesos realizados al estar en el contexto de la IS se ocupan de las prácticas de la disciplina, en particular prácticas para desarrollar y mantener componentes y sistemas de software tanto de manera individual, como en equipo. Por otro lado, dos artículos se centraron solamente en uno de los dos esquemas de trabajo, el esquema individual (Darejeh & Salim, 2016) y por el otro el de equipo (Hernández, Muñoz, Mejia, & Peña, 2016).

PI-6. ¿Qué elementos de gamificación han sido utilizados como estrategia en la ingeniería de software?

Después de analizar los estudios secundarios se pudo determinar que los elementos de gamificación más referidos son: los puntos, las insignias y las tablas de clasificación; por el contrario, los menos utilizados fueron: las limitaciones, los estados de ganador, el azar, los bienes virtuales entre otros como muestra el Figura 4. También se pudo determinar que el elemento de equipos estuvo presente en tres artículos.

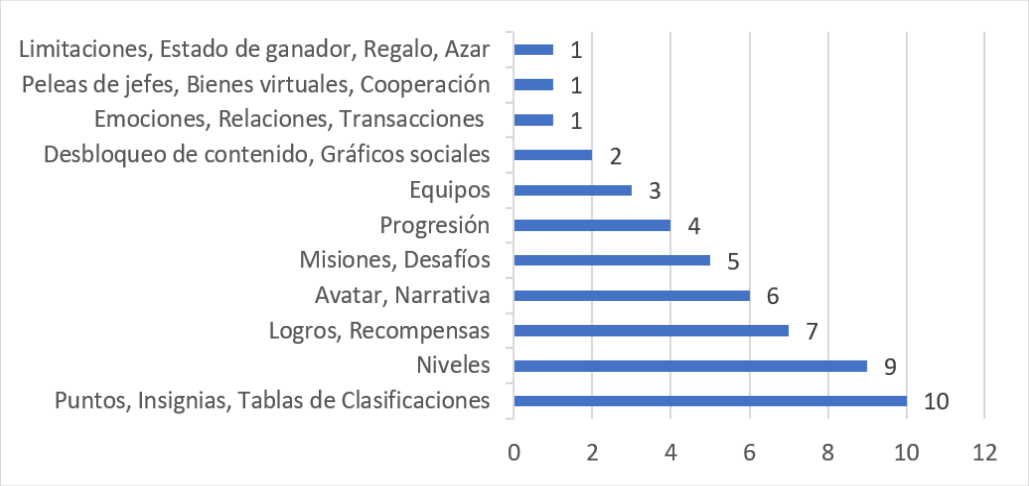


Figura 4. Elementos de Gamificación más utilizados en los estudios secundarios analizados.

Por otro lado, respecto de las herramientas utilizadas, como se observa en la Tabla 4 que se agrupan según el tipo de implementación con que fueron creadas, dichas herramientas cuentan con prestaciones como chat, reportes de retroalimentación semanal, generadores de preguntas, cuestionarios, tutoriales, recibir notificaciones, sección de noticias, etc.

Tipo de implementación	Herramientas
Nuevas plataformas gamificadas desarrolladas.	eMgage WReSTT-CyLE Classgame TeamFeed Gamiware DMGame Garuso
Plataformas gamificadas existentes.	HALO
Plug-in de gamificación/extensión a una herramienta no gamificada existente.	Redmine ALEF Trello
Ninguna plataforma de gamificación especial/herramienta utilizada.	Moodle

Tabla 4. Herramientas Gamificadas con su tipo de implementación.

7. CONCLUSIONES

El análisis de las publicaciones de los estudios secundarios sobre gamificación en IS en la ventana de tiempo del 2015 al 2024 revela una baja y decreciente frecuencia de publicaciones, lo que nos lleva a la conclusión de que la investigación realizada ha sido limitada en este campo. En cuanto a los contextos donde se aplicó la gamificación en la IS, la industria es el sector con mayor número de publicaciones. La distribución homogénea de estudios entre Revisiones Sistemáticas de Literatura (RSL) y Estudios de Mapeos Sistemáticos (EMS) subraya la importancia de ambos enfoques, pero resalta la necesidad de continuar explorando ambos tipos para obtener una comprensión más completa. La mayoría de los estudios abordan esquema de trabajo individual y en equipo, destacando elementos como puntos e insignias, pero menos limitaciones y bienes virtuales. Otro de los hallazgos es que la gamificación ha demostrado ser efectiva en la promoción de habilidades blandas esenciales para el trabajo en equipo. Con base en el estudio reportado, los investigadores identifican como nicho de oportunidad de investigación, podría ser el experimentar con estrategias de gamificación para consolidar y optimizar el trabajo en equipo que se realiza en los procesos de desarrollo software.

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ESPECIAL

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Rockin' the Subsurface: Learning Geophysics with 'Electromagnetic Odyssey

Explorando el Subsuelo: Aprendiendo Geofísica con 'Odisea Electromagnética

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Abstract. In the education of applied geophysics, innovative learning tools are essential to bridge the gap between theory and practical field experience. Fieldwork is critical for reinforcing classroom knowledge and fostering peer interactions. However, it faces financial costs, physical accessibility, and logistical challenges, which can deter student participation and create equity concerns. To address these issues, adaptable educational models and digitalization are crucial. Integrating Information and Communication Technologies (ICT) has significantly enhanced learning processes, with alternatives like recorded fieldwork videos, high-resolution imagery, and virtual outcrop models gaining prominence, particularly during the COVID-19 pandemic. Through thoughtful design, video games offer educational potential by enhancing motivation and engagement. This paper introduces *Electromagnetic Odyssey*, an immersive learning tool to overcome traditional field trips' financial and logistical constraints. The video game considers the application of Electromagnetic methods for groundwater exploration. *Electromagnetic Odyssey* aims to promote equitable access to quality education and motivate students through well-designed, technology-enhanced activities, aligning with educational principles emphasizing motivation's importance in learning.

Keywords: Game-based learning · Educational Video Games · Applied Geophysics · Groundwater exploration

Resumen. En la enseñanza de la geofísica aplicada, las herramientas innovadoras de aprendizaje son esenciales para cerrar la brecha entre la teoría y la experiencia práctica en el campo. El trabajo de campo es fundamental para reforzar los conocimientos adquiridos en el aula y fomentar la interacción entre compañeros. Sin embargo, enfrenta costos financieros, problemas de accesibilidad física y desafíos logísticos, que pueden desincentivar la participación estudiantil y generar preocupaciones sobre equidad. Para abordar estos problemas, son cruciales los modelos educativos adaptables y la digitalización. La integración de las Tecnologías de la Información y la Comunicación (TIC) ha mejorado significativamente los procesos de aprendizaje, con alternativas como videos de trabajo de campo, toma de imágenes de alta resolución y modelos virtuales de afloramientos, ganando protagonismo especialmente durante la pandemia de COVID-19. A través de un diseño cuidadoso, los videojuegos ofrecen un potencial educativo al mejorar la motivación y el compromiso. Este artículo presenta Odisea Electromagnética, una herramienta de aprendizaje inmersiva para superar las limitaciones financieras y logísticas de las excursiones tradicionales. El videojuego considera la aplicación de métodos electromagnéticos para la exploración de aguas subterráneas. Odisea Electromagnética tiene como objetivo promover el acceso equitativo a una educación de calidad y motivar a los estudiantes a través de actividades bien diseñadas y mejoradas con tecnología, alineándose con los principios educativos que destacan la importancia de la motivación en el aprendizaje.

Keywords: Aprendizaje basado en juegos · Videojuegos Educativos · Geofísica Aplicada · Exploración de Aguas Subterráneas

1 Introduction

In the area of applied geophysics, there is a growing need for innovative learning tools to bridge theory and practical field experience. Fieldwork is essential in geophysics education as it reinforces classroom knowledge and fosters peer-to-peer interactions, enhancing students' learning experiences. Despite the necessity of fieldwork in geophysical education, various barriers exist, including financial, physical, and cultural challenges [1–3]. Costs for equipment and field clothing of- ten fall on [2], and accessibility issues, including stress from physical and mental health problems, further complicate participation [3]. Logistical problems like weather and accommodation can negatively impact student experiences [4]. Disabilities may make fieldwork inaccessible, and equity concerns arise for students with external responsibilities [5]. Short field trips can distract new students with safety and social concerns, potentially deterring them from pursuing [6]. Therefore, it is imperative to recognize and overcome these obstacles to ensure equal access to high-quality educational experiences in geophysical exploration [7].

To address these obstacles, adaptable educational models and online systems are essential. They can mitigate financial and logistical issues, providing equal access to quality education. Integrating Information and Communication Technologies (ICT) in education has enhanced learning processes [8, 9]. Technological alternatives, such as recorded fieldwork videos, high-resolution imagery, and virtual outcrop models [10, 1], have become more prominent, especially during the COVID-19 pandemic, which has accelerated the adoption of virtual field trips (VFTs) [11].

Alternatively, video games also offer educational potential, enhancing motivation and engagement through flow, involvement, and enjoyment [12]. Research highlights the importance of designing technology-enhanced learning (TEL) activities to provide adequate motivational stimuli. Recognizing that technology alone does not guarantee motivation, thoughtful activity design is crucial [13]. This paper introduces *Electromagnetic Odyssey*, an immersive learning tool for applied geophysics. It addresses traditional field trips' financial and logistical constraints, promoting equitable access to high-quality education. This tool aims to motivate students through well-designed, technology-facilitated activities, aligning with educational principles emphasizing motivation's importance in learning [14].

2 Related Work

2.1 Virtual Field Trips

Barth's [17] study introduces a virtual field trip (VFT) on Google Earth Web to explore Yosemite Valley's geology using satellite imagery and 360 photospheres. The VFT consists of four parts: an overview, analyzing El Capitan's geologic map, creating a geomorphic map of Quaternary deposits, and a hazard assessment for infrastructure planning, enhancing students' decision-making skills. While discovery learning in virtual environments fosters independent problem-solving, it can increase cognitive load for those with limited geology knowledge. VR offers immersive VFT experiences [19, 20] but requires specialized, often scarce equipment. A practical alternative is a custom HTML web page, integrated maps, 3D models, and external links, making VFTs more accessible and comprehensive [10]. Moreover, Ruberto et al. [11] compared the learning outcomes of in-person (ipFT) and virtual (iVFT) geoscience field trips to Grand Canyon National Park. The iVFT, which used 360° images with interactive overlays, resulted in significantly greater cognitive and affective learning gains than the ipFT. However, ipFT students showed higher pre-trip excitement. The study suggests well-designed iVFTs can achieve better learning outcomes than tradiional in-person field trips.

2.2 Virtuality in Geophysics

Lin's [15] study introduces a method for projecting multi-layered remote sensing and geophysical survey data into a 3D immersive VR environment for non-invasive archaeological exploration. Using StarCAVE, they detail data collection, processing, and visualization to create a "virtual excavation" in a 3D VR setting. The study highlights the importance of immersive 3D visualization where physical exploration is impractical. In 2020, Xianying et al. [16] developed a VR visualization framework for geophysical big data, using in-memory computing for GIS

(Geographic Information System) spatial analysis. This framework supports mainstream rendering engines and VR hardware, making it accessible with open-source tools. Demonstrated with abyss trench data, the framework shows VR's superiority over traditional displays by reducing distractions, offering ample display space, enabling multidimensional analysis, and providing an interactive experience. The goal is to create a versatile VR data visualization toolbox for various scientific fields, using Spark and ParaView. Arecco et al. [18] developed a virtual reality (VR) classroom experience tailored for Petroleum and Geodesy-Geophysics Engineering courses. The VR software enables students to familiarize themselves with various reservoir models, including hydro, geothermal, and oil reservoirs, by allowing them to virtually dive and explore these environments using VR glasses and two joysticks as navigation tools. Guided by instructions provided in the teacher's Guidance Guide, students navigate the virtual environment while the teacher monitors their progress on a tablet, offering real-time guidance throughout the different stages of exploration. Students are also able to compare their findings with those of their peers, and they submit reports based on their observations. These reports are subsequently evaluated using rubrics provided by the instructor.

3 Electromagnetic Odyssey Design

We follow a participatory design approach to develop a game specifically tailored to students in applied geophysics. We established a cooperation with the Department of Applied Geophysics at the CICESE Research Center, Ensenada, Mexico. This collaboration provides us access to geophysical researchers specialized in electromagnetic methods. With their expertise, we gain further insights into geophysical students' learning and training requirements.

In the participatory design sessions, we identify key areas where students typically face challenges and determine the essential concepts that the game should address. These insights ensure that the game content is relevant and beneficial to the student's educational needs.

We use the MDA (Mechanics, Dynamics, and Aesthetics; [21]) framework to structure the game's development. This framework guides us in designing the game's core elements. Applying the MDA framework, we systematically are crafting an educational, engaging, and enjoyable game for the students. Mechanics refers to a game's fundamental elements, controls, and structure. They encompass the rules and components implemented within the game, including basic actions, algorithms, the game engine, and various game elements. Dynamics belong to the game's context, constraints, choices, chance, consequences, completion, continuation, competition, and cooperation. They describe how the game's mechanics operate in response to player inputs and interact with other mechanics. In addition, Dynamics shape the players' overall experience and emotional responses (aesthetics). Regarding Aesthetics, it relates to aspects such as the game's challenge, recognition, confidence, awareness, creativity, contribution, community, and adherence. Aesthetics also describes the emotional responses and feelings players experience while engaging with the game.

4 Results

4.1 Game Design

From the three components of the MDA framework, we identified some features according to the analysis of game design models in education using this framework by Kusuma et al.[22].

Mechanics

- Genres and Topics. A walking simulator, or walking sim, is a type of adventure game primarily focused on exploration and interaction with the environment. These games typically lack combat mechanics or conventional win/lose conditions, though they may occasionally incorporate puzzle-solving elements. Students are free to explore the scenarios.
- Levels (Level-Up System). The student needs to answer the problem; even if the choice is incorrect, the student advances to the next level, the *Storage room*. At this level, the student must complete the list of items required for the field campaign; once completed, the student moves to the next level, the field. The student must deploy the equipment or items using the correct electromagnetic method.

- Drag and Drop. In the game, this mechanic is in the *Storage* level, where students must select and place each item to complete the list. The student then deploys the items at the *Field* level according to the method.
- Mini-Games. There are two mini-games or mini-tasks at the *Field* level. One is designed for students to dig and bury the electrode by clicking with the mouse. The other is for balancing and orientating the coil.
- Feedback. After the student answers the problem, a pop-up window with feedback on the selected method appears. The final screen in the game provides direct feedback to the student regarding all the setups of the method.

Dynamics

- In-Game Exploration. The student is free to explore the virtual world of the game. Although the *Storage* space is small, students can walk freely; for the *Field* level, the world is expansive enough to walk and deploy the elements.
- Hints. In the *Storage room*, the list serves as feedback, informing the student which elements must be taken and which are still missing. A connection or task can only be completed at the *Field* level if all the components are collected.
- Timer. There is a timer for both the *Storage* and *Field* levels. The task at the *Storage* level is more straightforward than the *Field* level; therefore, the timer is shorter (10 minutes). For the *Field* level, because students need more time to deploy the elements, the timer is set to 20 minutes.
- Punishments. Students need to hydrate frequently; otherwise, they lose. To accomplish this, they need to select a water bottle from their items and activate it regularly. Wearing a hat can slow the depletion of the hydration bar.

Aesthetics

- Challenge. The students must complete the *Storage* level to advance to the next level. They need to memorize the items from the list, then grab and drop them into the van within the allotted time. For the *Field* level, students must complete all the connections and setup of the elements within the time limit, and they also need to manage their hydration.
- Discovery. Students discover new things through exploration or by trying new strategies to accomplish tasks at either the *Storage* or *Field* level.
- Sensation. Students may feel a sense of pleasure after completing the list at the *Storage* level or when they complete the mini-tasks or establish a connection.
- Narrative. The storyline that engages students is that all the tasks, activities, and levels mirror those they would perform in a real field campaign, following the same order, methodology, and logic.

Electromagnetic Odyssey begins with a menu screen (Fig.1a). When students click the play button, they are taken to a screen with a problem description (Fig.1b). The student must choose the correct method to solve the problem. After making a choice, a pop-up provides feedback. Afterwards, the game moves to the *Storage* level (Fig.1c). Here, the student collects all the necessary equipment for a field campaign using the chosen method. They must gather and load all the items into a van until the list is complete. Once all items are collected, the student advances to the *Field* level (Fig.1d). At this level, the student takes the item

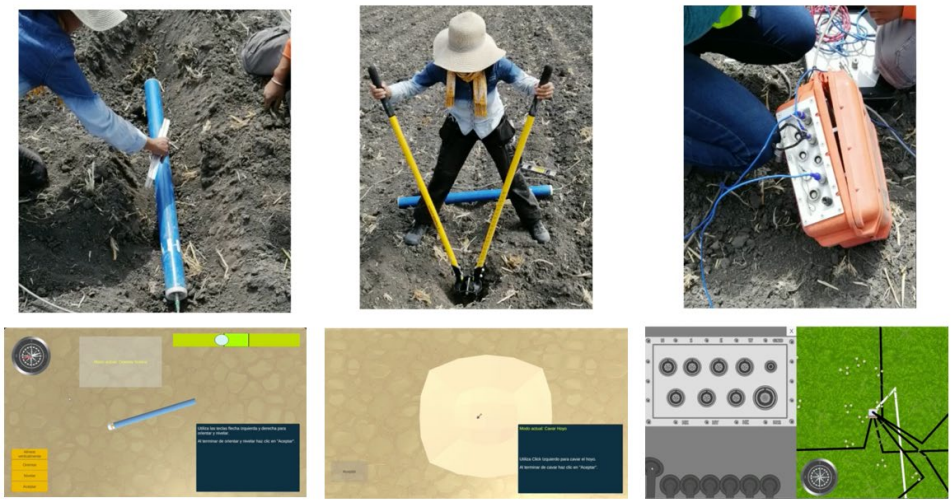
(a) Starting screen (b) The Problem (c) *Storage* level

(d) The *Field* (e) Results (f) PC controls

Fig. 1: Electromagnetic Odyssey main screens

one by one and sets them up in the terrain according to the chosen method. The final screen shows the results of the connections and item deployments (Fig.1e).

We tried to keep tasks in the game as close to reality as possible. For instance, in the field, students must orient and balance a coil (Fig.2a), dig a hole to bury an electrode (Fig.2b) and connect cables to the equipment (Fig.2c). These activities are simulated through mini-games (Fig.2).



(a) Orienting and balancing the coil (b) Digging and burying the electrode (c) Connecting the equipment

Fig. 2: From reality to virtuality. This figure shows the different dynamics and mechanics we implemented for some of the tasks in the field.

4.2 Feedback

Three students participating in the Geophysics Summer School 2023 at CICESE provided feedback after playing the Electromagnetic Odyssey once. Their comments reflect a range of positive and negative aspects and memorable experiences with the game.

Positive Aspects: One student (S1) mentioned that playing the game before a field campaign "helps you to perform better" and emphasized that "it helps you to follow certain steps and considerations and to remember the stuff." Another student (S2) noted that playing the game beforehand provided "a clearer and better idea regarding what to do." Similarly, a third student (S3) described the game as "a good tool before a field campaign."

Negative Aspects: In terms of drawbacks, the students highlighted a few areas for improvement. Student S1 pointed out that "the time is not enough to accomplish all the tasks without a guide" and noted that "it does not save the progress; so if you fail, you need to start from the beginning." Student S2 echoed concerns about time, stating, "After the field day, I was too tired to play it, but I think the time is insufficient in a first trial without a guide." Finally, Student S3 remarked that "a guide is missing," which suggests a need for additional support or instructions during gameplay.

Memorable or Impactful Aspects: The students also shared some memorable and impactful aspects of their experience. Student S1 compared the experience to "playing Minecraft," describing it as "a particular feeling." Student S2 found humor in how the game influenced real-life behavior, mentioning, "I was constantly drinking water because I remembered the hydration bar and to use my hat; it was funny." On the other hand, Student S3 expressed discomfort, noting that they "felt uncomfortable because I used to play games on a console, not a PC."

Overall, the students underscored the potential of *Electromagnetic Odyssey* as a valuable tool for pre-field campaign preparation and in educational settings such as online classes. They recognized its ability to enhance the quality of education, particularly in environments with limited resources. The students were pleasantly surprised by the integration of scientific content into the game, commenting that this approach is uncommon in many universities, where there is often a need for more equipment or initiative to incorporate scientific methods into teaching.

5 Conclusions and Future Work

Incorporating innovative learning tools into applied geophysics education is crucial for bridging the gap between theoretical knowledge and practical field experience. While fieldwork is critical in reinforcing classroom learning and fostering peer interactions, its accessibility often faces financial, physical, and logistical challenges, resulting in student equity concerns. Immersive learning environments promise to enhance students' learning through motivation and engagement. These environments must consider how the students acquire knowledge,and the designers translate that knowledge into game mechanics, dynamics, and aesthetics. Therefore, the involvement of specialists in the design is crucial to achieve the learning goals. This paper introduces *Electromagnetic Odyssey*, an immersive learning tool to overcome the financial and logistical constraints associated with traditional field trips in geophysics. *Electromagnetic Odyssey* exemplifies educational principles that emphasize motivation in the learning process by ensuring equitable access to high-quality education and motivating students through technology-enhanced activities. As one of the pioneering games designed to teach electromagnetic methods in geophysics, *Electromagnetic Odyssey* is accessible to most students. Our future work will assess usability and game experience, with plans for a long-term study to evaluate learning outcomes.

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ESPECIAL

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Desarrollo de un agente inteligente capaz de jugar un videojuego de peleas

Development of an Intelligent Agent Capable of Playing a Fighting Video Game

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Abstract. Los videojuegos son una herramienta importante como campo de pruebas de algoritmos de aprendizaje por refuerzo, sin embargo, también son una buena herramienta para generar inteligencia artificial para los mismos. Esta investigación se dividió en dos fases generales, el desarrollo de un demo de videojuego de peleas llamado Brain Fighter y la creación de un modelo de aprendizaje por refuerzo basado en el algoritmo llamado Proximal Policy Optimization para entrenar un agente inteligente de modo que sea capaz de jugar satisfactoriamente Brain Fighter.

En este artículo se presenta el mejor modelo obtenido como resultado de haber experimentado con seis modelos diferentes, además se expone la metodología utilizada para llevar a cabo toda la investigación, que constituye desde la creación de Brain Fighter en Unity, la elección del algoritmo de aprendizaje por refuerzo a utilizar disponible en ML Agents, la creación del modelo, el entrenamiento y los resultados obtenidos además de las conclusiones generales del trabajo.

Keywords: Inteligencia Artificial, Videojuegos, Agente inteligente, Proximal Policy Optimization, Aprendizaje por refuerzo, Self Play, ML Agents, Unity

Abstract. Video games are an important tool as a testing ground for reinforcement learning algorithms; however, they are also a valuable resource for generating artificial intelligence within games themselves. This research was divided into two general phases: the development of a fighting video game demo called Brain Fighter and the creation of a reinforcement learning model based on the Proximal Policy Optimization algorithm to train an intelligent agent capable of playing Brain Fighter satisfactorily.

This article presents the best model obtained as a result of experimenting with six different models. It also details the methodology used to carry out the research, which includes the creation of Brain Fighter in Unity, the selection of the reinforcement learning algorithm available in ML Agents, the development of the model, its training process, the results obtained, and the general conclusions of the work.

Keywords: Artificial Intelligence, Video Games, Intelligent Agent, Proximal Policy Optimization, Reinforcement Learning, Self-Play, ML Agents, Unity

1 Introducción

Los videojuegos son una herramienta esencial como campo de pruebas para el aprendizaje por refuerzo (Tipo de aprendizaje automático (Tantawi PhD, 2023)) debido a que permiten simular características del mundo real, sin embargo, los videojuegos también se pueden beneficiar de los avances en el campo de la inteligencia artificial, pues con ayuda de esta tecnología es posible crear recursos gráficos e incluso comportamiento avanzado para los personajes no jugables.

El objetivo de este trabajo es exponer la forma como se creó y diseñó un agente inteligente que sea capaz de jugar un videojuego de peleas utilizando el aprendizaje por refuerzo y el algoritmo que lleva por nombre “Proximal Policy Optimization” (Más delante en este trabajo, se explica en que consiste este algoritmo).

En la actualidad existen varios proyectos que se han desarrollado con éxito utilizando el aprendizaje por refuerzo. Por ejemplo, Daniel Sarrià Pascual realizó una investigación con el objetivo de mejorar la calidad de los bots de Rocket League utilizando el algoritmo Proximal Policy Optimization y aprovechándose de la herramienta RLBot (Sarrià Pascual, 2022) (Plataforma dedicada al desarrollo, personalización y competición de bots en el videojuego Rocket League (Community, 2024)).

2 Marco Teórico

Para el desarrollo de este trabajo, fue esencial entender varios conceptos del campo de la inteligentica artificial, a continuación, se describe cada uno de los temas en los que se basó este trabajo de manera breve.

2.1 Aprendizaje por refuerzo

El aprendizaje por refuerzo (RL) se centra en diseñar métodos para abordar problemas de toma de decisiones secuenciales. Un agente toma decisiones seleccionando acciones basadas en la información proporcionada por su entorno. Una pieza crucial de esta información es la señal de recompensa, que sirve como retroalimentación de que tan bien o mal lo está haciendo el agente inteligente. El objetivo del agente es maximizar su recompensa acumulada a lo largo de cada episodio de entrenamiento (Landers & Doryab, 2023; Sutton & Barto, 2018).

En el aprendizaje por refuerzo, los algoritmos se dividen en dos categorías principales: basados en valor y basados en políticas. Los algoritmos basados en valor se enfocan en calcular el valor de acciones o estados para derivar una política óptima (estrategia que define qué acción debe tomar un agente en cada estado del entorno). Por otro lado, los algoritmos basados en políticas aprenden directamente una política óptima ajustando la probabilidad de elegir acciones beneficiosas.

Una red neuronal profunda en conjunto con un algoritmo de aprendizaje por refuerzo es a lo que se le conoce como aprendizaje por refuerzo profundo (DRL). La red neuronal permite que el aprendizaje por refuerzo se adapte a problemas de toma de decisiones que antes eran intratables, es decir, entornos con espacios de acción y estados de alta dimensionalidad (Biscontini, 2023).

2.2 Proximal Policy Optimization

El algoritmo Proximal Policy Optimization (PPO) pertenece a la categoría de algoritmos basados en políticas que a su vez pertenece al área del DRL e introduce una nueva noción: la proximidad (parámetro que garantiza que, al actualizar una política, no se aleje demasiado de sus valores actuales).

Este enfoque se inspira en el concepto de “recorte”, que tiene como objetivo limitar el alcance de las actualizaciones para evitar cambios abruptos. El resultado es una convergencia más estable y un mejor rendimiento del aprendizaje (Gu et al., 2022).

PPO sigue un enfoque iterativo: el agente interactúa con el entorno, recopila datos de entrenamiento, actualiza sus políticas de acuerdo con el principio de proximidad y luego repite el proceso para mejorar el rendimiento del agente con el tiempo (Gu et al., 2022).

2.3 ML Agents

El conjunto de herramientas de Unity llamado ML-Agents es un proyecto de código abierto que posibilita a investigadores y desarrolladores la creación de entornos simulados mediante el editor de Unity, permitiendo la interacción a través de una API de Python. Este conjunto de herramientas incluye el SDK de ML-Agents, que contiene todas las funciones necesarias para definir entornos en el editor de Unity.

Las características destacadas del conjunto de herramientas abarcan varios entornos de ejemplo y algoritmos de aprendizaje por refuerzo de última generación como PPO. Además, ofrece soporte para Self-Play en juegos simétricos y asimétricos, junto con la posibilidad de mejorar el desempeño de los algoritmos con el Módulo de Curiosidad Intrínseca (ICM) y la Célula de Largo Corto Plazo (LSTM) (Juliani et al., 2018).

2.4 Self Play

Self Play es una técnica utilizada en el aprendizaje por refuerzo cuando se requiere entrenar un agente inteligente que aprenda a jugar un juego de suma cero (por ejemplo, un juego de peleas 1 contra 1). Prácticamente el agente compite contra sí mismo partiendo de una política completamente aleatoria y conforme las iteraciones de entrenamiento pasan, el agente comienza a mejorar su política hasta converger en una estrategia óptima (SaturnCloud, 2023)

3 Brain Fighter

Brain Fighter (Figura 1) es un demo de videojuego de peleas desarrollado en Unity (motor gráfico). Cuenta con un personaje jugable capaz de realizar ocho golpes distintos, caminar, brincar y cubrirse. Está demo se desarrolló para tener un entorno para el modelo de RL y aunque actualmente existen algunas herramientas que nos evitan tener que desarrollar todo un entorno porque proporcionan una interfaz de comunicación entre algún juego existente y los modelos de RL, como Gym (OpenAI, 2018), no tienen la flexibilidad que se buscaba para poder experimentar (Entiéndase flexibilidad como la posibilidad de elegir de manera libre los datos que el agente inteligente recibirá en su entrenamiento).

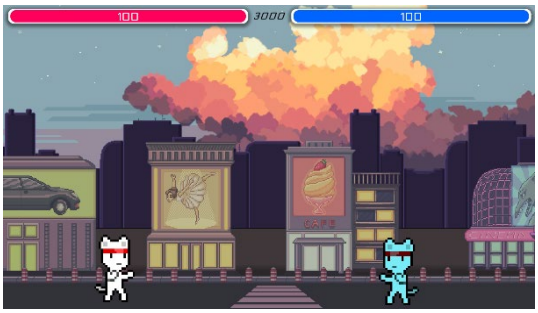

Fig. 1. Demo de Brain Fighter

4 Metodología

A modo de resumen, la Figura 2 describe las etapas que se llevaron a cabo para la realización de esta investigación. La construcción del videojuego, la selección del modelo de aprendizaje y la construcción del agente inteligente son la base de todo este trabajo porque es necesario disponer de un videojuego con posibilidad de acceso al código fuente o disponer de una forma para extraer información del juego con el fin de reunir los datos necesarios que requiere el algoritmo de aprendizaje, en este caso, se desarrolló todo el videojuego y se eligió el algoritmo PPO como algoritmo de aprendizaje por refuerzo a utilizar.

Por último, la construcción del agente inteligente implicó escoger la información que se utilizaría para entrenar, es decir, las observaciones, las señales de recompensa y las acciones posibles a realizar por el agente inteligente.

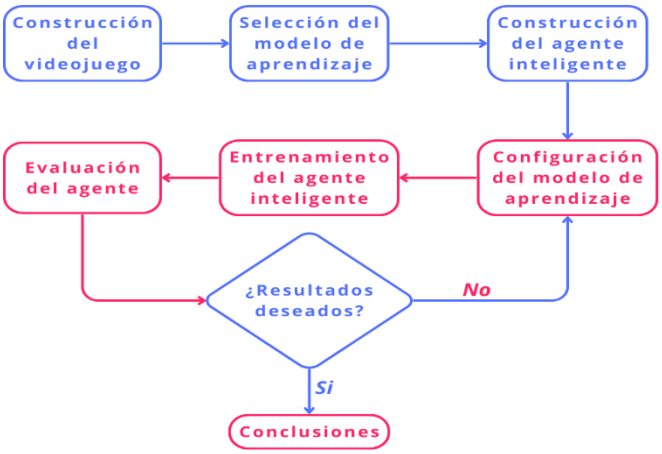

Fig. 2. Diagrama de la metodología

5 Diseño del modelo para entrenar un agente inteligente

Se diseñaron seis modelos para trabajar con ML-Agents variando los datos que el agente inteligente utilizó para entrenarse, sin embargo, solo hubo un modelo que se desempeñó correctamente en las métricas de evaluación que se presentan más delante en este trabajo y por ende los otros cinco modelos se descartaron. A continuación, se expone a detalle este modelo, el cual lleva por nombre “Modelo Delta”.

5.1 Modelo Delta

Este modelo utiliza el algoritmo PPO implementado en la herramienta ML-Agents y dio como resultado un agente inteligente que es capaz de seguir al enemigo y realizar ataques de manera satisfactoria. La tabla 1 y 2 muestra las características del modelo.

Características del modelo.

Acciones.

- No hacer nada
- Caminar
- Retroceder
- Saltar
- Golpe débil, ligero, fuerte y especial (acciones individuales)
- Patada débil, ligera, fuerte y especial (acciones individuales)
- Bloquear

Observaciones	**Posibles valores**
Estado de bloqueo del enemigo	Verdadero o Falso
Estado de daño del enemigo	Verdadero o Falso
Estado de bloqueo del agente	Verdadero o Falso
Dirección del enemigo	-1 o 1
Distancia muy cercana entre agente y enemigo	Verdadero o Falso
Vida del agente mayor a cero	Verdadero o Falso
Vida del enemigo mayor a cero	Verdadero o Falso
Resistencia del agente mayor a cero	Verdadero o Falso
Golpes encadenados	(0,1)

Tabla 1. Información (observaciones) proporcionada por el modelo

Evento que genera recompensa	Valor
Reducir distancia con el enemigo	+ 0.1
Golpear al enemigo	+ 0.075
Bloquear un ataque	+ 0.025
Incapacitar al enemigo	+ 0.075
Atacar al enemigo mientras bloquea	+ 0.025
Aumentar distancia con el enemigo	- 0.1
Recibir daño	- 0.075
Incapacitado	- 1
Ganar	+ (1 – recompensa acumulada)
Perder	- (1 – recompensa acumulada)

Tabla 2. Recompensas proporcionadas por el modelo

Ajustes adicionales.

- Enmascarado de acciones que no se pueden hacer cuando otra acción las bloquea mediante código
- Recompensa por curiosidad activada y Self Play activado
-

6 Mecanismos de evaluación para el agente inteligente

Cada vez que se entrena un agente inteligente con un modelo, se generan datos con los cuales se puede medir el rendimiento del modelo. Con esos datos se generaron gráficas del comportamiento del agente como son:

a. Gráfica de la recompensa acumulada del agente inteligente
b. Gráfica de la longitud de los episodios (Iteraciones de entrenamiento)
c. Gráfica de la pérdida de la política del agente inteligente
d. Gráfica de la pérdida de valor (Exactitud para predecir los estados futuros)
e. Gráfica de la entropía del agente inteligente
f. Gráfica de ELO del agente inteligente (Habilidad del agente inteligente)

Así mismo, el modelo se evalúa de manera visual con cuatro comportamientos que el agente debería de realizar. A continuación, se describen los cuatro comportamientos y las observaciones que pueden tener cada uno:

a. El agente inteligente se dirige hacia su enemigo: (Siempre, a veces, nunca)
b. El agente inteligente ataca cuando debe ser y no al aire: (Siempre, a veces, nunca)
c. Cantidad de golpes diferentes que el agente inteligente realiza: (1-8)
d. El agente inteligente bloquea cuando debe de ser: (Siempre, a veces, nunca)

7 Resultados

Los resultados que se obtuvieron al entrenar un agente inteligente con el modelo Delta fueron satisfactorios. Para respaldar lo anterior, se presentan las tres gráficas más importantes para la evaluación del agente inteligente, las cuales son: La gráfica de la recompensa acumulada, la gráfica de pérdida de la política y la gráfica de ELO del agente inteligente, además de los puntajes que se obtuvieron en la evaluación visual.

7.1 Resultados de la evaluación visual del agente inteligente entrenado con el modelo Delta

El modelo Delta se desempeñó excelente en tres de los cuatro comportamientos de la evaluación visual, siendo el último el único en el que el agente inteligente falló.

a. El agente inteligente se dirige hacia su enemigo: **Siempre**
b. El agente inteligente ataca cuando debe ser y no al aire: **Siempre**
c. Cantidad de golpes diferentes que el agente inteligente realiza: **6**
d. El agente inteligente bloquea cuando debe de ser: **Nunca**

7.2 Gráficas generadas del entrenamiento con el modelo Delta

En base a las figuras 3, 4 y 5 se puede concluir que el modelo Delta está bien diseñado porque el comportamiento de las figuras muestra a un agente inteligente capaz de maximizar sus recompensas y aumentar su habilidad (ELO) sin variar demasiado las decisiones que toma en cada iteración de entrenamiento (política del agente).

La figura 3 muestra una tendencia que aumenta conforme pasan las iteraciones de entrenamiento, es decir, el agente inteligente logró satisfactoriamente incrementar su recompensa recibida utilizando las acciones proporcionadas por el modelo Delta.

Fig. 3. Recompensa acumulada del agente inteligente usando el modelo Delta

La figura 4 representa la diferencia entre una política anterior y una actual. Un valor bajo representa una variación pequeña en las decisiones tomadas por el agente inteligente, es decir, el agente inteligente es consistente y estable en sus decisiones.

Fig. 4. Pérdida de la política del agente inteligente usando el modelo Delta

La figura 5 representa la habilidad del agente inteligente frente a su rival, mientras más habilidad mejor desempeño existe en comparación con el rival (esta característica solo está presente con modelos que utilizan Self Play). En este caso hay complicaciones para derrotar al rival porque el ELO no aumenta mucho respecto a su valor inicial.

Fig. 5. ELO del agente inteligente usando el modelo Delta

8 Conclusiones

Con base en los resultados obtenidos, podemos concluir que el aprendizaje por refuerzo en conjunto con el algoritmo PPO crean agentes inteligentes capaces de aprender a jugar un videojuego de peleas de manera satisfactoria.

El comportamiento del agente inteligente dependerá del diseño del modelo, es decir, que las observaciones y las recompensas otorgadas al agente inteligente juegan un papel crucial en el comportamiento que tendrá el mismo. Además, es muy importante que las recompensas estén correctamente balanceadas y que, en la medida de lo posible, las recompensas se mantengan simples y alcanzables para el agente inteligente, de otro modo, posiblemente el agente inteligente nunca descubrirá la existencia de esas recompensas.

Es posible crear agentes inteligentes que representen dificultades mayores o menores, como ya se dijo, el comportamiento de un agente inteligente depende del modelo. Con esto en mente es posible crear agentes inteligentes que sean más agresivos o defensivos o incluso una combinación de ambos.

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ESPECIAL

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Validation of the Emotions&Care App: A MobileApplication for Supporting Mental Health of College Students

Validación de Emotions&Care: una aplicación móvi para apoyar la salud mental de estudiantes universitarios

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Abstract

College students have experienced an increment in mental health issues due to the COVID-19 pandemic. When students start college, their mental health can be affected by emotional, social, or academic requirements. It is essential to provide tools for supporting the mental health of this population. In this paper, we present the validation of the Emotions&Care app, a mobile application for supporting the mental health of college students. Emotions&Care follows a user-centered design and provides mental health screening and monitoring. We used gamification techniques to motivate the sustained use of the app. Emotions&Care also allows mental health specialists to monitor college students' mental health by tracking daily notes and emotions and by controlling appointments. We validated Emotions&Care with eleven college students and four mental health specialists. Our results indicate that Emotions&Care has the potential to provide college students with mental health screening and monitoring; however, several design issues should be addressed to ensure its extended-term use.

Keywords— College students, Mental health, Mobile app.

Resumen

Los estudiantes universitarios han experimentado un aumento de los problemas de salud mental debido a la pandemia de COVID-19. Cuando los estudiantes comienzan la universidad, su salud mental puede verse afectada por requisitos emocionales, sociales o académicos. Es importante proporcionar herramientas para apoyar la salud mental de esta población. En este artículo, se presenta la validación de Emotions&Care, una aplicación móvil para apoyar la salud mental de los estudiantes universitarios. Emotions&Care sigue una metodología de diseño centrado en el usuario y proporciona detección y seguimiento de la salud mental. Utiliza técnicas de gamificación para motivar el uso sostenido de la aplicación. Emotions&Care también permite a los especialistas en salud mental monitorear la salud mental de los estudiantes universitarios a través del seguimiento de notas, emociones diarias y el control de citas. Emotions&Care fue validada con once estudiantes universitarios y cuatro especialistas en salud mental. Los resultados indican que Emotions&Care tiene el potencial de proporcionar a los estudiantes universitarios detección y seguimiento de la salud mental; sin embargo, se deben abordar varios problemas de diseño para garantizar su uso a largo plazo.

Palabras clave— Estudiantes universitarios, salud mental, aplicación móvil.

1 Introduction

The World Health Organization (WHO) defines mental health as *a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and can make a contribution to his or her community"* (World Health Organization, 2004). Mental health is an integral part of an individual's general health and well-being and a basic human right. Good mental health means people are better able to connect, function, cope, and thrive. Mental health exists on a complex continuum, with experiences ranging from an optimal state of well-being to debilitating states ofgreat suffering and emotional pain (World Health Organization, 2022).

College students have experienced an increment in mental health issues due to the COVID-19 pandemic. When students start college, their mental health can be affected by emotional, social, or academic requirements. Several studies have documented the impact of the COVID-19 pandemic on the mental health of college students (Salimi, Gere, Talley, & Irioogbe, 2023; Wang et al., 2020), indicating an increased difficulty in concentration, sleeping, and eating patterns as well as an increase in social isolation, concerns about academic performance, and overall disruption in well-being (Salimi et al., 2023).

A sign of poor mental health is depression, which is not just about being sad or disinterested; it can lead to suicidal behavior. Suicide is related to most severe mental disorders, and in the case of people with depression, the risk is 21 times higher than in the general population. According to the WHO, suicide is the second cause of death in people between 15 and 29 years of age, ranging from high school to completion of college studies (Auerbachet al., 2019).

The mental health issues that college students might experience can lead them to seek help professionally or research themselves on the topics of interest. However, it is well knownthat much of the information on the internet today may come from an unreliable source or need better support (Ramón-Arbués et al., 2020).

The development of new technologies can be used to develop innovative ways to support college students' mental health. More than 10,000 mobile applications (apps) are available for download on mental health for evaluation or treatment of mental disorders. For example, the WHO recommends *"promoting self-care through mobile and electronic health technologies"* (López-Santín & Álvaro Serón, 2018). However, many of these mobile applications are not designed according to the user's needs and without the support of mental health specialists.

In this paper, we present the validation of the Emotions&Care app, a mobile application for supporting the mental health of college students. A complete design iteration of Emotions&Care using the Design Thinking methodology (T. Brown, 2008) was previously reported in (anonymous for review). We used the first design validation results to improve the application and develop a high-fidelity prototype. We validated the new version with eleven college students and four mental health specialists. Our results indicate that Emotions&Care has the potential to provide college students with mental health screening and monitoring; however, several design issues should be addressed to ensure its long-term use.

2 Related work

Mobile apps for screening mental health are available in the literature. For example, the study of (BinDhim et al., 2015) presents a cross-sectional study of a depression screening mobile app containing a patient health questionnaire, a brief anxiety test, and personalized recommendations based on the user's results. Eight thousand two hundred forty-one participants from 66 countries downloaded the app, with a response rate of 73.9%. While one-quarter of the participants had a previous diagnosis of depression, the prevalence of participants with a higher risk of depression was 82.5%. The authors concluded that mobile apps could deliver a screening tool for depression across many countries.

Regarding the college student population, some studies have shown how app-based intervention can support depression (Lahtinen, Aaltonen, Kaakinen, Franklin, & Hyönä, 2023; Lattie et al., 2022). The study of (Lahtinen et al., 2023) presents a 4-week randomized controlled trial with 561 college students divided into a treatment group (publicly available mindfulness app) and an active control group (psychoeducational online content). Results showed that using the mindfulness app for four weeks resulted in small reductions in stress and depression. These results show that mindfulness apps offer modest but clear benefits to users in terms of improved mental health.

We systematically searched applications using Google Play and the App Store to investigate what commercial applications have been developed to support students' mental health. We use four keywords related to the research topic: Depression, anxiety, mental health, and students.

The search results show a great variety of commercial Apps. In particular, 25 apps were available on Google Play, and over 100 were in the App Store in April 2024. We analyze the search results to investigate commercial applications that are aimed at mental health, treating symptoms of depression and anxiety, and aimed at university students. We extract app information, including the app name, main characteristics, target users, scientific evidence, availability of the evidence, screenshots of the graphic user interfaces, and advantages and disadvantages according to user reviews.

We also verified whether the apps had scientific evidence supporting their effectiveness and efficiency. We searched scientific papers on PubMed, the Journal of Medical Internet Research (JMIR), Scopus, ScienceDirect, EBSCO, ProQuest, Frontiers, and Google Scholar. In the following paragraphs, we describe the most relevant apps found.

The Wysa app (Chang, Sinha, Roy, & Wong, 2024) includes a Chatbot for anxiety using Artificial Intelligence. The advantages are that it provides audio and video sessions with a therapist and has a library of more than 150 self-care tools with scientific support. Some disadvantages are that it limits human interaction, is inappropriate for all cases, and is expensive.

The Sanvello app (Litvin et al., 2023) includes mindfulness techniques, meditation exercises, and personal attention. However, personalized attention is limited, complete access is expensive, and social support is limited. Similarly, the Calm app (May & Maurin, 2021) includes meditation, mindfulness, and breathing exercises. The disadvantage is that some content is only available through an optional paid subscription.

Finally, the Youper app (Potts et al., 2023) includes depression, anxiety, personality, panic, and social anxiety tests. The drawbacks are that paying to see the progress graphs is necessary and does not offer behavioral therapy.

The overall findings in the analysis of the search results indicate that there are many applications for mental health to treat symptoms of depression and anxiety; however, they are not focused on university students—also, the majority lack scientific evidence. Additionally, many have negative comments specific to the special functions of mental health management.

3 Research Methodology and Prior Work

We are following the Design Thinking methodology (T. Brown, 2008), a user-centered design approach that allows iteration and contributes to solving solutions for difficult and complex problems by understanding users' needs and developing appropriate solutions to support them (Pereira, Parizi, Prestes, Marczak, & Conte, 2021). Design Thinking consists of five phases: (1) Empathize, (2) Define, (3) Ideate, (4) Prototype, and (5) Test. The first iteration of the methodology was published in (Guevara Rodriguez et al., 2023). This paper presents the second iteration of the methodology, going forward, and backyards between the prototype and test phases. We used the first iteration results from the test phase to improve the app's design and build a high-fidelity prototype (a second iteration). We validated the high-fidelity prototype with eleven college students and four mental health specialists. Next, we describe the second iteration of the Emotions&Care App, following the results of the validation sessions with college students and mental health specialists.

4 The Emotions&Care App: Second Iteration

The Emotions&Care App is a mobile application designed to support college students' mental health. The app's main features include mental health screening, recommendations, daily notes, emotion tracking, specialists' appointment tracking, and community. Emotions&Care also includes a mental health specialist module, where specialists can monitor college students' mental health.

4.1 Mental health screening and recommendations

Emotions&Care uses the Beck Depression Inventory-Second Edition (BDI-II) (Figure 1(a, b)), a 21-item self-report rating inventory that measures characteristic attitudes and symptoms of depression. The BDI-II results range from absent or minimal depression to severe depression (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961)(Figure 1(c)). Emotions&Care does not provide a mental health diagnosis; it informs the user about their possible mental health status and always recommends going to a mental health specialist.

Once the college student finishes the mental health screening through the standardized tests, the app invites her to continue using it, providing daily mental health recommendations (Figure 1(d)). We surveyed scientific studies that provide recommendations for improving and balancing mental health. We grouped the recommendations into five categories: diet, sleep, physical activity, social life, and relaxation techniques.

4.2 Mental health monitoring

College students can write daily notes using the app to monitor their mental health (Figure 2(a)). Additionally, college students can add emotion to each note (Figure 2(b)). In this way, college students can monitor their daily notes and emotions through different visualizations (Figure 2(c)). Mental health specialists can also use Emotions&Care to monitor the mental health of college students, observing their daily notes, emotions, and test results. Specialists and college students can manage therapy appointments. College students can also search for mental health specialists according to a therapeutic approach, proximity location, or other related search filters.

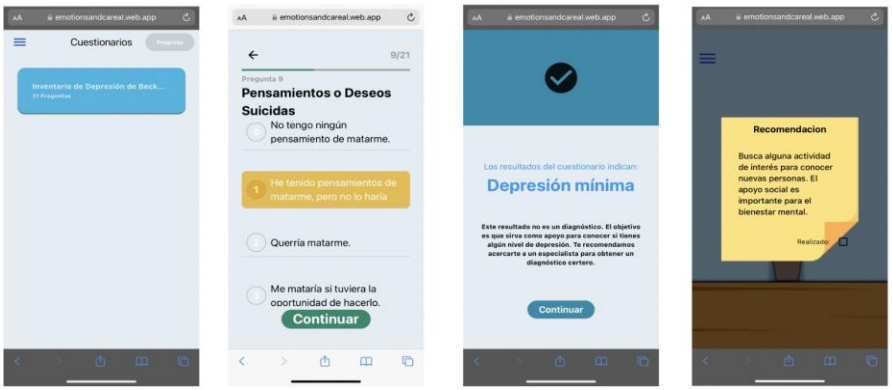

Figure 1. Mental health screening and recommendations features of the Emotions&Care app. (a) Screening test available; (b) BDI-II Questionnaire fragment; (c) Results of the BDI-II Questionnaire; (d) Example of social life recommendation.

4.3 Gamification techniques

Gamification involves applying game design elements in non-game contexts. It has demonstrated its potential to foster user motivation, engagement, and enjoyment in computer-mediated environments (Seaborn & Fels, 2015). In web-based mental health interventions, several studies have suggested that incorporating game mechanics could improve treatment adherence and program engagement (M. Brown et al., 2016; Hopia & Raitio, 2016).

Emotions&Care adopted a gamification approach based on fundamental psychological principles, such as self-determination theory and intrinsic and extrinsic motivation (Seaborn & Fels, 2015). Multiple gamification elements have been incorporated to encourage user engagement and adherence. First, a visual feedback and progression system was implemented using a flower growth metaphor (Figure 3(a, b)). The flower grows and advances to new levels as the user completes tasks and achieves goals, providing a tangible representation of individual progress. This approach is based on the experience systems commonly used in video games, which reward positive actions and progress toward goals (Zichermann, 2011).

Additionally, the application awards a badge upon meeting certain milestones, taking advantage of the extrinsic motivation and sense of achievement these digital rewards can generate (Figure 3(d)). On the other hand, social engagement loops have been incorporated to allow users to send anonymous notes of encouragement to other community members (Figure 3(c)). This mechanic encourages positive interactions and a sense of belonging while encouraging re-entry into the application to continue interacting and receive feedback (Zichermann, 2011).

The gamification design of Emotions&Care is based on a combination of intrinsic motivations (such as personal growth represented by the flower) and extrinsic motivations (such as badges and social recognition), following the recommendations of the literature on effective gamification techniques (Seaborn & Fels, 2015; Zichermann, 2011).

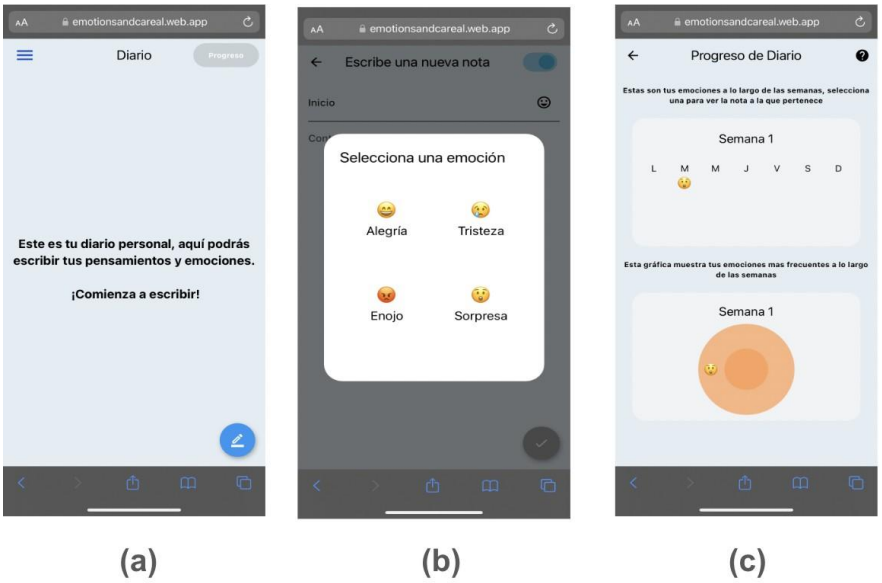

Figure 2. Daily notes and emotion tracking features of the Emotions&Care app. (a) Daily note's introduction; (b) Emotions available for adding to each daily note; (c) Visualizations for tracking emotions.

5 Emotions&Care Validation Sessions

5.1 Methods

We conducted two validation sessions, one with eleven college students (five females; average age = 21 years; SD = 2.5 years; seven participants had attended therapy sessions) and one with four mental health specialists (three females; average age = 42.5 years; SD = 3.7 years, all psychologists). In each session, we explained the project's goals. Then, with the guidance of the research team, each participant interacted with the high-fidelity prototype of the app. We asked them to carry out tasks with the application related to its functions. Finally, each participant answered a short survey consisting of demographic information and the System Usability Scale (SUS) Questionnaire to measure usability. The short survey also included open-ended questions to investigate participants' qualitative perceptions of the prototype. At the end of the session, we thanked our participants for helping us validate the app. For mental health specialists, we also used the Technology Acceptance Model (TAM) (Silva, 2015) to measure perceived usefulness and ease of use.

5.2 Results

Table 1 shows college students' and mental health specialists' average scores from the SUS Questionnaire. A SUS score above 68 would be considered above average, and anything below 68 is below average. According to Table 1, college students and mental health specialists obtained a score below the average, which may indicate usability problems

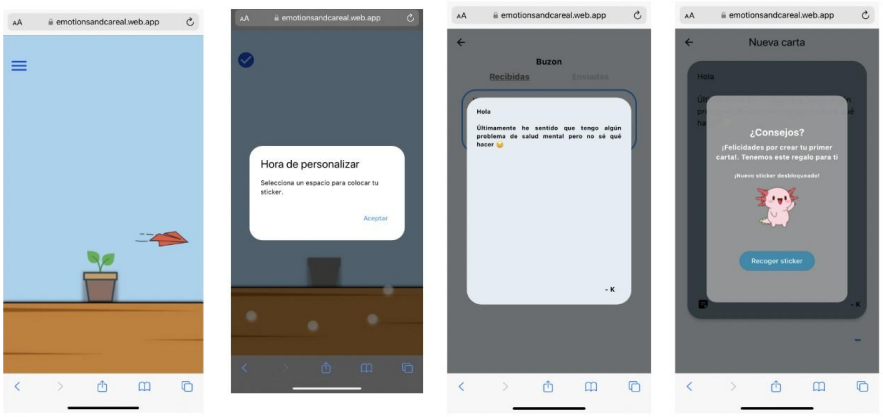

Figure 3. Gamification techniques. (a) The flower growth metaphor; (b) Personalization options for placing badges; (c) Community feature; (d) Example of a badge(digital rewards).

encountered with the interface. During the validation session with college students, several issues regarding functionality emerged, which could have caused an impact on perceived usability. On the other hand, mental health specialists expressed that they were confused with some functions and icons when looking for options to solve the assigned tasks.

Regarding the TAM results, we obtained an average score of 5.20 for usefulness and

5.18 for the ease-of-use dimension, which is above average. This indicates that Emotions &Care was perceived as useful and easy to use.

From the qualitative results, most college students mentioned that their favorite part of Emotions&Care was the daily notes and emotion tracking. They also enjoyed the flower growth metaphor and the community module. Their most minor favorite aspect was consulting the appointment schedule with their mental health specialist. One reason for this is that this module had many functionality problems since it did not save the appointments made in the agenda, and the application had to be restarted several times.

Mental health specialists mentioned that their favorite app feature was monitoring the mental health of college students through daily notes, test results, and emotion tracking. Some suggestions for improving the app were changing the icons, adding more tests for mental health screening, and allowing mental health specialists to add specific recommendations according to the college student's needs. The four specialists agreed that Emotions&Care can optimize the specialist's work and facilitate access to mental health services; however, they mentioned that correcting icons and errors in

Table 1: SUS Scores by participants' group.

Participants' group	SUS Score
College Students	62.27
Mental Health Specialists	62.50

functionalities and reviewing thelegal aspect of data use is essential.

Conclusions and future work

This paper presents the Emotions&Care validation with eleven college students and four mental health specialists. Emotions&Care is designed to support mental health screening and monitoring using several gamification techniques. The validation results show that there are still some design issues to address before deploying Emotions&Care with college students and mental health specialists. However, participants perceived Emotions&Care as a useful tool for supporting mental health. In the future, we plan to integrate more standardized tests to screen for depression, anxiety, and other mental health disorders. We also plan to integrate the validation results into a new app iteration and deploy it to study its long-term use. Finally, considering their specific needs, we plan to offer different types of licenses or memberships to offer Emotions&Care services to different universities.

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ESPECIAL

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Beat by Beat: Designing a Rhythm Game forScreening Dyslexia.

Paso a Paso: Diseñando un Juego de Ritmo para la Detección de la Dislexia

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Abstract. Dyslexia, a language-based disorder, affects children's reading, writing, and spelling abilities despite adequate classroom instruction. Early screening is crucial to mitigate the adverse effects of delayed detection. Dyslexia also impairs precise timing tasks, including rhythm skills essential for reading. This study explores the potential of serious games incorporating rhythms to screen for dyslexia, leveraging the natural synchronization of rhythm skills observed in body movements. Existing rhythm games fail to accurately address dyslexia-related difficulties, lacking relevant performance data and user-centred design. Our research aims to design a 2D sidescrolling platformer game, integrating established rhythmic activities to identify children at risk for dyslexia and engage them in gameplay. A multidisciplinary team collaborates on this initiative, including neuropsychologists, music therapists, and game designers. Using the Design Thinking Methodology, we focus on identifying effective music compositions, game mechanics, dynamics, and visual elements that enhance the gaming experience for children with dyslexia and support early dyslexia screening.

Keywords: screening dyslexia · rhythm video games · user-centered design

Resumen: La dislexia, un trastorno del lenguaje, afecta las habilidades de lectura, escritura y ortografía de los niños a pesar de una instrucción adecuada en el aula. La detección temprana es crucial para mitigar los efectos adversos de la detección tardía. La dislexia también afecta las tareas de sincronización precisa, incluidas las habilidades rítmicas esenciales para la lectura. Este estudio explora el potencial de los juegos serios que incorporan ritmos para detectar la dislexia, aprovechando la sincronización natural de las habilidades rítmicas observadas en los movimientos corporales. Los juegos de ritmo existentes no abordan con precisión las dificultades relacionadas con la dislexia, ya que carecen de datos de rendimiento relevantes y un diseño centrado en el usuario. Nuestra investigación tiene como objetivo diseñar un juego de plataformas de desplazamiento lateral en 2D, integrando actividades rítmicas establecidas para identificar a los niños en riesgo de dislexia e involucrarlos en el juego. Un equipo multidisciplinario colabora en esta iniciativa, que incluye neuropsicólogos, musicoterapeutas y diseñadores de juegos. Utilizando la metodología Design Thinking, nos centramos en identificar composiciones musicales efectivas, mecánicas de juego, dinámicas y elementos visuales que mejoren la experiencia de juego para los niños con dislexia y respalden la detección temprana de la dislexia.

Palabras clave: cribado de dislexia · videojuegos rítmicos · diseño centrado en el usuario

1 Introduction

Dyslexia manifests as a condition in children where, despite conventional classroom instruction, they struggle to achieve language skills in reading, writing, and spelling that match their intellectual capabilities [1]. Individuals with dyslexia face challenges with precise timing tasks, including rhythm skills that positively affect reading abilities. One of the reasons is that music and languages are common mechanisms, and thus, transfer effects from the former to the latter are expected to occur [2, 3]. Therefore, the lack of rhythm can indicate a dyslexia condition [4–6] characterized by difficulties in fluent reading. Several studies have shown a correlation between different rhythm tests and reading abilities [7–14, 18, 20, 21, 4]. Synchronization to a musical beat relies on a sophisticated neuronal network comprising perceptual regions, motor regions, and sensorimotor integration areas [22]. In the case of children with dyslexia, this disorder affects auditory-motor synchronization to a musical beat [22, 12], as well as other functions such as speech. Thus, researchers have proposed that music training could address these dyslexia timing issues [23].

In this context, serious games offer engaging, multisensory experiences to support therapies for children with neurodevelopmental disorders. With low cost and broad accessibility, they are well-suited for attending to diverse patient populations and environments. For instance, there are games to address auditory hyper-sensitivity using interactive virtual reality [24] and web-based games to screen dyslexia using music components [27], among others. While video games are used for early dyslexia screening, the potential of rhythm-based activities remains underexplored. Current rhythm games lack the necessary data to predict dyslexia risk and do not cater to the needs of therapists or psychologists. Understanding users' behavior is critical for creating design strategies that enhance and support dyslexia screening; furthermore, it is necessary to explore the use of rhythms for early detection. Therefore, based on the 2D sidescrolling platformer rhythms-based game *Jump'n'Rhythm* [28, 29], we propose a user-centred design focused on children with dyslexia. This initiative involves a multidisciplinary team comprising neuropsychologists, music therapists, and game designers. What is the most effective music composition for a video game, incorporating rhythms and rhythmic activities established in the literature, to identify children at potential risk for dyslexia and motivate them during the gameplay? Which game mechanisms and dynamics are needed to engage children with dyslexia? Which visual elements enhance the gaming experience for children with dyslexia? We used the ground theory and Design Thinking methodology to answer these questions.

2 Related Work

2.1 Dyslexia and Music

Tierney et al. [19] examine the role of rhythm processing in dyslexia, focusing on two factors: sequencing (perceiving and reproducing rhythmic patterns) and synchronization (maintaining consistent timing with stimuli). Sequencing is linked to reading ability and verbal memory, correlating with better performance in language and cognitive tasks. Meanwhile, synchronization relates to nonverbal auditory processing and phonological skills in preschoolers, school-aged children, and early adolescents [3, 12, 14]. The findings suggest rhythm perception, mainly through musical training, can enhance phonological processing, reading skills, and verbal memory [11]. Rhythmic priming may also support language processing, memory encoding [15], and grammaticality judgments [16]. [17] assessed the consistency of auditory brainstem responses across a recording session by measuring brainstem responses to speech syllables from normal-hearing children ages 6–13 years with a wide range of reading abilities. Results show that poor reader have significantly more variable auditory brainstem responses to speech than good readers, independent of resting neurophysiological noise levels. Overy [5] proposed that group music lessons focused on singing and rhythm games could serve as an effective multisensory support tool for dyslexic children by fostering the development of essential auditory, motor timing, and language skills. A research program was subsequently developed, which included the creation of group music lessons and musical tests tailored for dyslexic children, alongside three experimental studies. The findings revealed that classroom music lessons positively impacted phonological and spelling abilities but did not improve reading skills. Additionally, the results indicated dyslexic children struggled with musical timing skills but did not exhibit difficulties with pitch recognition.

2.2 Video Games for Dyslexia

Several digital tools are available for early dyslexia screening. *Dytective* [30] is a web-based game challenging players to accumulate points by solving linguistic problems within time-limited stages. Participants are presented with a target letter or non-word, displayed alongside similar-sounding distractors. *Diesel-X* [31] comprises three mini-games assessing skills associated with early dyslexia markers: distinguishing frequency-modulated tones, phonological awareness through word recognition, and letter knowledge. *Nessy* [32] is educational software. It focuses on core literacy skills such as phonemic awareness, phonics, spelling, and reading fluency. Interactive activities include matching sounds to letters, identifying syllables, word building, and sound categorization. An auditory game, *DysMusic* [27], adapted from the visual Memory game, aims to detect differences in sound perception between children with and without dyslexia. Players match musical elements hidden behind digital cards, varying tasks to test short-term memory.

2.3 Rhythm Video Games for Therapy

Bégel [22] and Dalla [10] evaluated games for training rhythmic and auditory-motor skills, considering factors like device precision and output modality. Of 27 games reviewed, none were suitable for rhythm rehabilitation - most focused on reacting to visual cues with background music rather than directly emphasizing rhythm. Poor device temporal precision also limited accurate rhythmic performance measurement. Bégel [25] then developed *Rhythm Workers*, a serious game explicitly targeting perceptual and sensorimotor rhythmic abilities. It involves constructing buildings using rhythmic patterns and musical stimuli, with versions for beat perception and synchronized tapping. Experiments showed it effectively improved rhythm skills in healthy adults after two weeks of training, suggesting potential for rehabilitating rhythm disorders. Vonthron's [26] *Mila- Learn* serious game for remote education was tested with over 5,800 children during COVID-19 lockdowns. Iterative feedback improved motivation and customization. While performance increased over time, particularly for older children and those with ADHD, progress was slower among children with dyslexia.

3 Methods

We are using the Design Thinking methodology [33], an iterative user-centred design methodology which consists of five stages as detailed below:

Stage 1: Empathize— This stage concentrates on understanding the user's needs. We garnered insights from the literature concerning the rhythm skills of children with dyslexia and their relationship to language. This literature review provided valuable context and foundational knowledge for our research. Subsequently, we conducted user research through seven semi-structured interviews involving three music therapists and four neuropsychologists. Each interview was recorded for analysis, amounting to 8.40 hoursof recorded material.

Stage 2: Define— We identified user needs and challenges in this stage. We analyzed the interview data using open and axial coding. During open coding, we segmented and analyzed the data of interest to identify concepts and categories. Subsequently, we systematically examined the data to determine relations between the categories and subcategories identified during the open coding phase. This qualitative analysis enabled us to generate our claims, assumptions, personas, and scenarios. Next, we will validate these scenarios with experts to ensure they address real user needs -three music therapists, three neuropsychologists, two music technologists, and one music pedagogies. These insights have become potential use cases for early dyslexia screening.

Stage 3: Ideate— With our scenarios finalized, we will engage therapists, neuropsychologists, and game designers in participatory design sessions. These sessions will serve as a platform for interdisciplinary collaboration, ensuring we challenge our initial assumptions and explore ideas. By incorporating the expertise of therapists and neuropsychologists, we will gain insights into the practical and clinical needs of early dyslexia screening. Meanwhile, the involvement of game designers will help us translate these insights into engaging and compelling game features. This collaborative effort aims to identify and develop the ideal features for an early dyslexia screening game.

Stage 4: Prototype— We will initiate the process by developing a prototype incorporating the main ideas generated during the ideation phase. This prototype will represent our concepts, enabling us to assess their feasibility and effectiveness. Initially, our team will share the prototype internally to gather preliminary feedback and make necessary refinements. Following this internal review, we will extend the testing to a small group of external experts, including therapists, neuropsychologists, and musicians. Their feedback will be crucial in identifying strengths and weaknesses and ensuring the prototype aligns with practical requirements and user expectations.

Stage 5: Test— After selecting the best solutions from prototyping, we will assess the final product through user experience and interaction evaluations. These evaluations will have two stages: formative assessments to refine usability and engagement and summative assessments to measure the tool's effectiveness in early dyslexia screening. While this marks the end of the initial five-stage process, design thinking is iterative. Any insights gained may lead to further refinements or identify new problems to address. This iterative approach ensures continuous improvement and maintains the tool's relevance and effectiveness over time.

4 Results

Based on the findings from Stages 1-3 of the Design Thinking methodology, we have created a list of design features for a 2D sidescrolling rhythm-based game [29] aimed at early dyslexia screening. Additionally, we have developed a game scenario using the storyboard technique. Our results are as follows.

4.1 Design Features

1. *Activities based on rhythm tests*: Our contextual research supports the integration of four rhythm tests, as proposed by Tierney [19], which focus on sequencing (perceiving and reproducing rhythmic patterns) and synchronization (maintaining consistent timing with stimuli). These tests are integral to our game design and are key tools for assessing rhythm processing in individuals with dyslexia. The game's mechanics are closely aligned with the rhythmic abilities targeted by these tests, which are often deficient in individuals with dyslexia:
   - Synchronization with a metronome: The person taps in sync with auditory stimuli at a fixed tempo (metronome) at three speeds: 90, 120, and 180 bpm.
   - Synchronization with a beat: The person taps while maintaining the tempo as auditory rhythmic sequences are played.
   - Synchronization with rhythmic sequences: The person taps synchronously with auditory rhythmic sequences.
   - Rhythm memory: The person listens to a rhythm sequence and then replicates the same sequence.
2. *Customization*: The video game design should prioritize children's autonomy by allowing them to personalize their experience by choosing the sequence of activities and selecting an avatar that resonates with their individual preferences and identity.
3. *Music*: Central to this project is the use of music, particularly rhythmic elements, to enhance children's motivation and engagement. Drawing from our contextual study, which included insights from music therapists, neuropsychologists, and music technologists, we focused on using percussion instruments. Experts emphasized the effectiveness of percussive elements in therapeutic settings, leading us to prioritize drums and rhythms in the composition of the game's music. This music is carefully designed to complement the visual elements, creating an engaging multisensory experience for children.

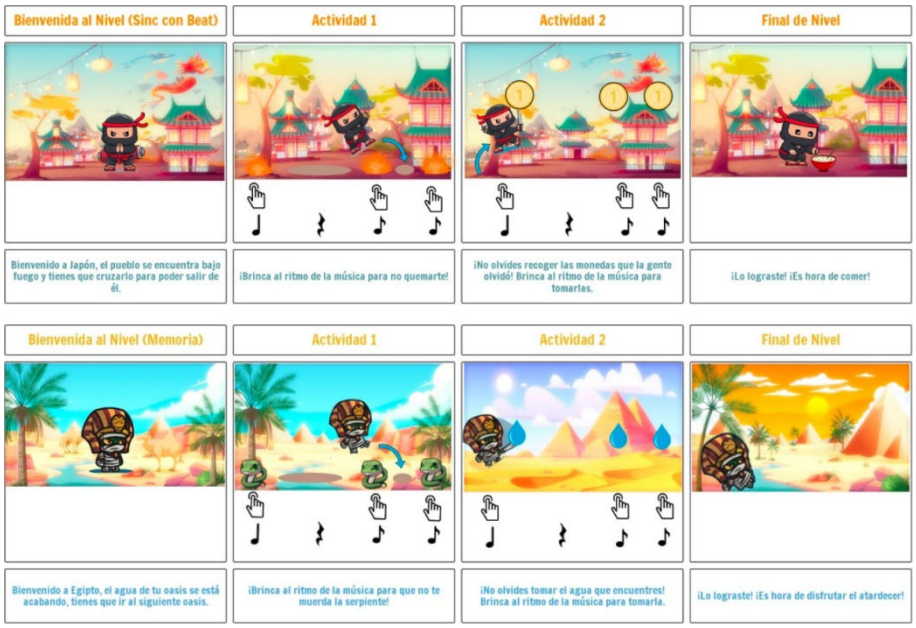

Fig. 1. A proposed game scenario. The figure shows a segment of the proposed story-board where the avatar jumps in sync with the rhythms, avoiding threats.

4. *Interface Design*: The visual elements of the game, including avatars and game worlds, are designed to be engaging and appropriate for children, with distinct scenarios for each activity or rhythm test. These visual design choices are informed by insights from our contextual study, where experts recommended a side-scrolling format. Consequently, the game was developed as a jump-and-run side-scrolling platformer.
5. *Instructions*: The video game should use audio for the tutorials and instructions because, as an early screening tool, the children may not know how to read and write. The audio for the tutorials and instructions will be agile, dynamic, and age-appropriate, without using condescending voices. Both children and therapists can skip the tutorials.
6. *Reinforcers*: The video game should include positive reinforcement. It should also incorporate partial reinforcers within each activity. Both partial and final reinforcers will be displayed on the screen through animations.
7. *Data Acquisition*: Our game incorporates rhythm tests adapted from the methodologies of Tierney [3, 19], who effectively distinguished between dyslexicand non-dyslexic participants to identify potential risks for having dyslexia. By recording the timing of user interactions, such as tapping in response to rhythmic stimuli, our game facilitates analysis akin to that utilized in the *Jump'n'Rhythm* game [28], which is the foundation for our design.

4.2 Initial Proposed Game Scenario

Inspired by our contextual study, we have developed ideas for a proposed game scenario using the storyboard technique, which will be showcased during our participatory design sessions. Figure 1 presents a segment of this storyboard tailored for our design sessions. With four rhythm tests [3] in mind, we have crafted unique scenes within a warrior-themed world. For example, we have chosen the Asia Kingdom setting for the synchronization test. Here, children are challenged to tap along with a metronome that changes tempo—shifting between 90 bpm, 120 bpm, and 180 bpm every forty beats. To represent the taps within the game, an avatar jumps when the children tap, synchronizing with the rhythm while navigating obstacles and avoiding traps. Similarly, we have envisioned a medieval kingdom for the test synchronizing with the beat. Children tap along with rhythmic music in this realm, guiding their avatar through challenges. Additionally, an Egyptian kingdom serves as the backdrop for the synchronizing with the rhythm test. Children tap in time with the music's rhythm, guiding their avatar's movements. Finally, the memory sequence test is set within a castle mission. Children listen to rhythmic musical sequences and then replicate them. Their avatar mirrors these sequences while navigating obstacles.

5 Conclusions and Future Work

This study explores integrating music and rhythm into serious games as a novel approach to screen for dyslexia. By leveraging the natural synchronization between rhythm skills and bodily movements, we designed a 2D side-scrolling platformer game. Our interdisciplinary collaboration and user-centred design approach aim to identify children at risk for dyslexia through engaging gameplay. Although our research is currently in Stage 3, preliminary results underscore the importance of customizable activities, compelling music compositions, visually attractive interfaces, and positive reinforcement. These features are crucial in creating an effective and enjoyable screening tool for early dyslexia detection.

Grounded in educational and cognitive theories emphasizing the significance of rhythm and timing in phonological and language skill development, particularly for individuals with dyslexia, our game's design reflects these principles. While formal studies with participants at Stage 5 have yet to be conducted, our contextual study, enriched by inputs from neuropsychologists, music therapists, and educators, confirms the appropriateness of the game's features for this stage. This alignment, coupled with the success of similar interventions in addressing Stage 5 needs, enhances our confidence in the game's potential efficacy.

The game's adaptability allows for modifications based on user feedback and continuous testing. As part of our iterative development process, we will conduct further evaluations with Stage 5 participants to refine and validate the game, ensuring it meets their specific needs.

Moving forward, our research will focus on several key areas to enhance the effectiveness and usability of the game for future work. We plan to conduct extensive user testing with both dyslexic and non-dyslexic children to gather detailed feedback on the gameplay experience, interface design, and the overall appeal of the game. This user testing will be accompanied by iterative design cycles, where we will incorporate the feedback into successive versions of the game, continuously refining its features.

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The Future of Gaming: How Artificial Intelligence is Revolutionizing the Industry

El Futuro de los Videojuegos: Cómo la Inteligencia Artificial está Revolucionando la Industria

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Abstract. Artificial Intelligence (AI) is not just a tool for improving video games; it is revolutionizing the entire industry. This opinion paper explores how AI is transforming gaming experiences, enhancing player engagement, and reshaping game design. We argue that AI's role in gaming is not just beneficial but essential for the future of interactive entertainment. Through an examination of current trends and future possibilities, we provide our perspective on the profound impacts of AI on the gaming world.

Keywords: Artificial Intelligence, Gaming, Player Engagement, Game Design, Machine Learning.

Resumen. La Inteligencia Artificial (IA) no es solo una herramienta para mejorar los videojuegos; está revolucionando toda la industria. Este artículo de opinión explora cómo la IA está transformando las experiencias de juego, mejorando la participación de los jugadores y reformulando el diseño de los juegos. Sostenemos que el papel de la IA en los videojuegos no solo es beneficioso, sino esencial para el futuro del entretenimiento interactivo. A través de una examinación de las tendencias actuales y las posibilidades futuras, proporcionamos nuestra perspectiva sobre los profundos impactos de la IA en el mundo de los videojuegos.

Palabras clave: Inteligencia Artificial, Videojuegos, Participación de Jugadores, Diseño de Juegos, Aprendizaje Automático.

1. Introduction

Artificial Intelligence (AI) is rapidly becoming the cornerstone of innovation across various industries, and the gaming industry is no exception. The evolution of AI technologies has fundamentally altered the landscape of video games, driving unprecedented levels of interactivity, immersion, and personalization [1]. In this paper, we aim to explore the transformative power of AI in gaming, offering insights into how these technologies are reshaping the industry and predicting future trends. We also address the ethical considerations that accompany these advancements.

Historically, video games have been limited by static designs and pre-scripted behaviors, which, while effective, often resulted in predictable and repetitive gameplay experiences. However, the advent of AI has introduced dynamic elements that can adapt in real-time to player actions, creating a more engaging and immersive environment [2]. This shift is not just a technical advancement but a paradigm change that redefines the relationship between the player and the game.

AI's role in gaming encompasses a wide range of applications, from enhancing non-player character (NPC) behaviors to generating entire game worlds procedurally [3]. The ability of AI to learn and evolve based on player interactions opens up new possibilities for creating personalized experiences that can cater to individual player preferences. This personalization is crucial in an era where players seek unique and meaningful engagements rather than generic gameplay [4].

Moreover, AI is instrumental in analyzing vast amounts of player data to provide insights that can drive game design and development. This data-driven approach allows developers to fine-tune their games, ensuring they meet the evolving expectations of the gaming community [5]. The integration of AI in gaming is not just about making better games; it's about creating experiences that resonate on a deeper level with players.

In this opinion paper, we will delve into specific AI applications in gaming, discussing their impacts, benefits, and the challenges they present. We will also explore the ethical considerations and potential future directions of AI in this dynamic industry. Our goal is to provide a comprehensive overview that highlights the significance of AI in gaming and its potential to shape the future of interactive entertainment.

2. The Transformative Power of AI in Gaming

We believe that AI is a game-changer in the true sense. Its integration into video games has moved beyond simple improvements to fundamentally altering how games are designed and experienced.

2.1. Adaptive Difficulty and Personalization

One of the most impactful applications of AI in gaming is adaptive difficulty, as exemplified by games like *The Legend of Zelda: Breath of the Wild*. In this game, adaptive difficulty is subtly implemented through a dynamic scaling system that adjusts the challenge based on the player's progression. As players defeat enemies and complete various tasks, the game tracks their achievements and gradually increases the strength and variety of enemies encountered, introducing tougher foes and more complex combat scenarios [6]. This ensures that the game remains challenging and engaging, regardless of the player's skill level or play style, fostering a sense of growth and mastery as players explore the vast open world of *Hyrule*. The balance between exploration, puzzle-solving, and combat is carefully maintained, allowing players to feel a sense of accomplishment without overwhelming them with difficulty spikes [7].

In a similar vein, *Metal Gear Solid 5* demonstrates how AI can dynamically adjust challenges to match the player's skill level, ensuring a consistently engaging experience. The AI Director in the game monitors real-time metrics such as player health, stress levels, and success rates, making on-the-fly adjustments to enemy spawn rates and item placements [8]. This adaptability is key to maintaining player interest and satisfaction in increasingly competitive and complex gaming environments. By tailoring various game elements, from enemy behaviors to environmental challenges, the AI ensures that players remain challenged without being overwhelmed, providing a tailored gaming experience that adapts to individual play styles [9].

Moreover, adaptive difficulty and personalization can significantly reduce frustration and enhance enjoyment, making games accessible to a broader audience, including those with varying skill levels [10]. For instance, *Mortal Kombat vs. DC Universe* dynamically adjusts the

behavior of opponents based on the player's performance, ensuring that matches remain challenging yet fair. This adaptability not only keeps players engaged by matching their skill level but also helps in maintaining a smooth learning curve, preventing both frustration for beginners and boredom for advanced players [11].

Another game that exemplifies AI-driven adaptive difficulty is *Alien: Isolation*. This survival horror game employs a sophisticated dynamic AI system that meticulously adjusts the behavior of the Alien in response to the player's actions. This adaptive difficulty system is designed to create a relentlessly tense atmosphere, as the AI constantly analyzes the player's strategies, such as hiding patterns and movements, and adapts its behavior accordingly. Whether by increasing the aggressiveness of the Alien when the player is performing well or offering brief moments of respite when the player is struggling, the system ensures that the intensity of the experience remains consistently high, making every encounter with the Alien uniquely challenging and unpredictable [12]. This AI-driven approach not only enhances the horror elements of the game but also ensures that it remains engaging for a wide range of players without diminishing the core experience for those seeking a more challenging playthrough.

2.2. Realistic NPC Behavior

Realistic non-player characters (NPCs) have always been a goal for game developers. AI has brought us closer to achieving this, as seen in games like *Grand Theft Auto 5* (*GTA 5*). NPCs that react realistically to player actions add depth and immersion to the game world. These advancements are crucial for creating truly immersive game environments. In *GTA 5*, NPCs exhibit behaviors based on a system of needs and relationships, allowing them to interact with the environment and the player in believable ways [13]. They can show a range of emotions, realistic responses to what happens around them, and react dynamically to the player's actions, contributing to a living, breathing world that feels authentic and engaging [14].

These realistic NPC behaviors are achieved through advanced AI techniques such as decision trees, behavior trees, and reinforcement learning [15]. By simulating human-like decision-making processes, NPCs can exhibit complex behaviors that enhance the overall gaming experience. For instance, an NPC might react with fear or aggression depending on the player's actions or develop relationships with the player based on past interactions [16]. This creates a sense of continuity and realism that traditional scripted behaviors cannot achieve [17].

Furthermore, AI-driven NPCs can contribute to dynamic storytelling by reacting to the unfolding narrative in real-time. This not only makes the game world more immersive but also allows for emergent gameplay, where unexpected and unique scenarios can arise from the interactions between the player and the NPCs [18]. This level of interactivity and unpredictability is what sets AI-driven games apart from their traditional counterparts.

Another notable example is *Red Dead Redemption 2*, where NPCs exhibit a wide range of behaviors and interactions, creating a vibrant and dynamic game world. NPCs remember past interactions with the player, leading to different responses and behaviors based on those encounters, enhancing the sense of a living, reactive world [19]. This memory system allows for continuity and consequence, making the player's actions feel meaningful and impactful in the game's world.

In *Alien: Isolation*, the AI that governs the behavior of the game's non-playable character (NPC) — the Alien itself — is one of the most advanced and terrifyingly effective AI systems in modern gaming. Unlike traditional NPCs that follow predictable patterns, the Alien's AI is designed to be highly adaptive and unpredictable, creating an intensely immersive experience. The Alien operates with two layers of AI: a macro-AI that knows the player's general location and guides the Alien towards them, and a micro-AI that controls its moment-to-moment actions, such as investigating noises, checking hiding spots, and reacting to player movements [20].

This dual-layer AI system ensures that the Alien feels both intelligent and menacing, as it learns from the player's actions and adapts its strategies over time. For example, if the player frequently hides in lockers or under tables, the Alien's AI will start searching these areas more thoroughly, forcing the player to constantly change tactics. The AI's ability to improvise and react to the player's behavior creates a sense of constant danger and unpredictability, making every encounter with the Alien a nerve-wracking experience [21]. This sophisticated AI design not only enhances the horror atmosphere of Alien: Isolation but also sets a new standard for how NPCs can be used to create dynamic and engaging gameplay experiences.

Moreover, NPCs enhanced by AI can engage in more natural and context-aware conversations with players. Using techniques such as natural language processing (NLP), NPCs can understand

and respond to a wider range of player inputs, making interactions feel more fluid and less scripted. In *Baldur's Gate 3*, AI-driven NPCs react dynamically to the player's choices in dialogue, offering branching paths and varied responses that make each conversation feel unique and impactful [22]. This approach not only enriches the narrative experience but also allows for a more personalized and immersive gameplay experience, as the world and its inhabitants genuinely reflect the player's decisions.

The *Last of Us Part II* also offers a remarkable example of AI-driven NPC behavior. The game's enemies exhibit realistic reactions to the player's actions, such as coordinating attacks, searching for the player based on sound cues, and responding emotionally to the deaths of their comrades. This level of detail contributes to the immersive and intense atmosphere of the game, making each encounter feel unique and personal [5].

2.3 Procedural Content Generation

Procedural content generation, as exemplified by *No Man's Sky*, allows for the creation of vast, unique game worlds. This not only extends the game's longevity but also provides a fresh experience with every playthrough [4]. This capability is essential for the future of open-world games and other genres that rely on expansive environments. AI algorithms generate planetary landscapes, flora, fauna, and atmospheric conditions, ensuring that each player's journey is unique. This approach reduces development time and costs while offering players endless exploration opportunities [23].

Procedural content generation leverages techniques such as fractal algorithms, Perlin noise, and Lindenmayer systems to create complex and varied environments [1]. These techniques enable developers to generate vast amounts of content algorithmically, rather than manually crafting each element. This not only saves time and resources but also allows for the creation of expansive game worlds that would be impractical to design by hand [24].

Moreover, procedural content generation can enhance replayability by ensuring that each playthrough offers a different experience. This is particularly important in genres such as roguelikes and survival games, where the unpredictability and variety of the game world are key to maintaining player interest [25]. By leveraging AI to generate content dynamically, developers can create games that offer endless possibilities and keep players engaged over the long term.

Games like *Minecraft* also use procedural content generation to create endless variations of worlds, encouraging creativity and exploration. The use of procedural algorithms ensures that no two game sessions are ever the same, providing a unique experience each time [15]. This capability allows for a high degree of player creativity and experimentation, as players can continually discover new landscapes and challenges [16].

Spelunky is a popular roguelike game that uses procedural content generation to create new levels every time the player starts a game. This approach not only ensures high replayability but also challenges players to adapt their strategies continually, as no two runs are ever the same [22]. AI algorithms in *Spelunky* generate complex, interconnected levels with varying difficulties, providing a fresh experience with each playthrough.

2.4 Dynamic Storytelling

Dynamic storytelling powered by AI, such as in *Detroit: Become Human*, enables narratives that evolve based on player choices. This creates a more personalized and engaging storytelling experience [13]. The ability to craft unique narratives for each player is one of the most promising developments in game design. AI tracks player decisions and adjusts the storyline accordingly, allowing for multiple possible endings and varied experiences [8]. This level of interactivity enhances replay value and encourages players to explore different paths and outcomes, deepening their engagement with the game [7].

Dynamic storytelling relies on AI techniques such as natural language processing, decision trees, and machine learning to create adaptive narratives. These techniques enable the game to respond to player choices in real-time, creating a branching narrative that can lead to a multitude of outcomes [9]. This not only enhances the replay value of the game but also allows players to experience a story that feels uniquely their own [12].

Furthermore, dynamic storytelling can enhance emotional engagement by creating a sense of agency and consequence. When players feel that their choices have a meaningful impact on the story, they are more likely to become emotionally invested in the game [10]. This can lead to more

memorable and impactful gaming experiences, as players are drawn into the narrative and motivated to explore different story paths [11].

Another example is *The Witcher 3: Wild Hunt*, where player choices significantly impact the game's story and world state. These choices lead to multiple endings and variations in the narrative, making each playthrough unique and deeply personal [17]. This branching narrative structure ensures that players are continually engaged and invested in the story, as they uncover new aspects of the game's world and characters with each decision.

Mass Effect 2 is another example where AI-driven dynamic storytelling plays a crucial role. The game tracks player choices across multiple narrative arcs, affecting relationships with NPCs, mission outcomes, and even the game's ending. AI enables the game to offer a branching narrative structure that responds to player decisions, providing a deeply personalized story experience [18].

3. Challenges and Ethical Considerations

While the benefits of AI in gaming are numerous, we must also address the challenges and ethical considerations

3.1 Technical Limitations

The computational power required for advanced AI applications can be a barrier for smaller developers. Ensuring that AI behaves predictably in complex environments is another technical hurdle [14]. As technology progresses, these limitations will become less significant, but they are important to acknowledge in the current landscape [3]. Additionally, the integration of AI requires significant expertise in both game development and machine learning, which can be a resource constraint for smaller studios.

Moreover, the real-time processing requirements for advanced AI systems can lead to performance issues, particularly on lower-end hardware. Developers must balance the benefits of sophisticated AI with the need to ensure smooth and responsive gameplay. This often involves optimizing AI algorithms and leveraging techniques such as hierarchical state machines and behavior trees to reduce computational overhead [1].

For instance, games with highly complex AI systems, like *Total War: Three Kingdoms*, require significant processing power to manage the large number of NPCs with sophisticated behaviors. This can result in performance issues on less powerful systems, necessitating careful optimization and balancing by developers to maintain a smooth gaming experience across a wide range of hardware configurations [16].

Another technical challenge is ensuring the predictability and reliability of AI behaviors. In complex game environments, AI systems must be robust enough to handle a wide range of player interactions without breaking immersion or leading to unintended consequences [3]. This requires extensive testing and refinement to ensure that AI behaviors align with the game's design goals and provide a consistent experience for players [25].

While the computational power required for advanced AI is a significant barrier, cloud gaming offers a promising solution. By offloading AI processing to powerful cloud servers, developers can create sophisticated AI-driven experiences that are accessible on a wide range of devices, from high-end gaming rigs to mobile phones [18]. This approach also allows for more scalable and flexible AI implementations, as resources can be allocated dynamically based on demand [23].

3.2 Ethical Issues

AI's capability to analyze player data raises concerns about privacy and data security. Moreover, the potential for AI to create addictive gaming experiences must be carefully managed [19]. Ethical considerations should be at the forefront of AI development in gaming to ensure responsible use of these powerful technologies [14]. AI-driven personalization, while enhancing player engagement, could be used to manipulate player behavior and encourage excessive gaming. Developers must strike a balance between creating engaging experiences and avoiding practices that exploit psychological vulnerabilities [20].

Additionally, the use of AI to analyze player behavior and preferences raises important questions about data privacy and consent. Players should be informed about how their data is being used and given the opportunity to opt-out if they do not wish to participate [21]. Developers

must implement robust data protection measures to ensure that player data is secure and used responsibly [18].

The issue of data ownership is also critical. Players should have control over their own data, and developers should be transparent about how it is collected, used, and stored. This transparency is essential for building trust between players and developers and ensuring that AI technologies are used ethically [19].

Moreover, there are concerns about the potential for AI to reinforce harmful stereotypes or biases. If not carefully designed, AI systems can inadvertently perpetuate biases present in their training data, leading to discriminatory behaviors in game characters or scenarios [20]. Developers must actively work to identify and mitigate these biases, ensuring that AI-driven games promote inclusivity and fairness [21].

The ethical considerations also extend to the psychological impact of AI-driven games. The immersive and engaging nature of these games can lead to excessive gaming or addiction, particularly among vulnerable individuals [19]. Developers must be mindful of the psychological effects of their games and implement features that promote healthy gaming habits, such as playtime reminders and parental controls [19].

To address ethical concerns, developers can implement AI ethics frameworks, such as the 'Ethical AI in Games' initiative, which promotes transparency, fairness, and accountability in AI-driven game design [20]. This includes practices like providing players with clear information about data usage, offering opt-in/opt-out choices, and ensuring that AI systems are regularly audited for bias and fairness.

3.3 Balancing Innovation and Regulation

The rapid advancement of AI technologies necessitates a careful balance between innovation and regulation [12]. While AI has the potential to revolutionize gaming, it also requires oversight to ensure fair and ethical use [21]. Regulatory frameworks should be established to protect player data, ensure transparency in AI decision-making, and prevent the misuse of AI for manipulative or harmful purposes [22].

Regulators and industry stakeholders must collaborate to develop guidelines and standards that promote the responsible use of AI in gaming [21]. This includes establishing clear policies on data privacy, consent, and transparency, as well as setting ethical standards for AI-driven game design [23]. By working together, the industry can ensure that AI technologies are used to enhance gaming experiences in a fair and ethical manner [22].

The role of government and industry bodies in regulating AI in gaming is crucial. They must work together to create frameworks that support innovation while protecting players from potential abuses [22]. This includes setting standards for AI transparency, ensuring that players understand how AI influences their gaming experience, and preventing practices that could lead to addiction or other negative outcomes [20].

Additionally, international collaboration is necessary to create consistent regulatory standards across different regions [22]. As the gaming industry is global, disparate regulations can create challenges for developers and players alike. By harmonizing regulations, stakeholders can ensure that AI-driven games meet ethical and safety standards worldwide [21].

In the context of innovation, it is important that regulations do not stifle creativity and progress. Regulatory frameworks should be designed to support experimentation and development while ensuring that ethical considerations are addressed [25]. This balance will enable the gaming industry to continue evolving and leveraging AI’s potential while safeguarding players ’rights and well-being [24].

4. Looking to the Future

The future of AI in gaming is incredibly promising. Advances in machine learning and natural language processing will lead to even more sophisticated and engaging games [23]. We envision AI-driven games that are not only more immersive and dynamic but also more inclusive, offering tailored experiences for players with diverse needs and preferences [24].

The intersection of AI with virtual reality (VR) and augmented reality (AR) will further revolutionize gaming [24]. AI could drive dynamic content generation in VR and AR, creating environments that adapt in real-time to player actions and preferences, providing a level of immersion and interactivity that is currently unparalleled [17].

The integration of AI with other emerging technologies, such as cloud gaming, will also expand the possibilities for game design and distribution [25]. AI-powered cloud gaming platforms could offer personalized gaming experiences without the need for high-end hardware, making advanced AI-driven games accessible to a wider audience [18].

Furthermore, the continued advancement of AI research will lead to new and innovative applications in gaming. For example, AI could be used to create more realistic and intelligent virtual assistants, enhance player feedback systems, and develop adaptive learning environments that tailor educational games to individual learners [25]. The potential for AI to transform gaming is vast, and we are only beginning to explore its possibilities [25].

The fusion of AI with other technologies such as blockchain could also offer new ways to create and monetize games [23]. Blockchain technology can ensure transparency and fairness in gaming transactions, while AI can enhance the game experience itself. Together, they can provide a secure and dynamic gaming environment where players have more control and ownership over their gaming assets [24].

5. Conclusions

Artificial Intelligence is not just enhancing video games; it is transforming them. From adaptive difficulty and realistic NPCs to procedural content generation and dynamic storytelling, AI is revolutionizing every aspect of game design and player experience [1]. While challenges and ethical considerations must be addressed, the future of AI in gaming is bright [4]. Continued innovation and responsible development will lead to a new era of interactive entertainment that is more engaging, immersive, and inclusive than ever before [7].

For developers, the implications are clear: embracing AI can lead to more engaging and dynamic games but must be balanced with considerations of ethical design and user safety [3]. For researchers, the field of AI in gaming presents a fertile ground for further study, particularly in understanding the long-term impacts of these technologies on society [12].

Ultimately, as AI continues to evolve, it will undoubtedly keep transforming the gaming industry in profound ways [14]. By addressing the current challenges and exploring the potential of new AI technologies, developers and researchers can ensure that this transformation benefits all stakeholders and leads to a more exciting, inclusive, and responsible gaming future [15].

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Supporting the cognitive development of individuals with intellectual disabilities through a video game for emotional regulation

Apoyo al desarrollo cognitivo de personas con discapacidad intelectual mediante un videojuego para la regulación emocional

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Abstract. Emotional regulation is a fundamental skill for the cognitive, social, behavioral, and academic development of individuals with intellectual disabilities. However, these individuals often face significant challenges in this area. Therapeutic interventions have been designed to improve emotional regulation. Nevertheless, most interventions and studies have been directed at other populations, such as individuals with autism spectrum disorder or ADHD. Some of them have been proven to be effective in supporting individuals with intellectual disabilities, yet a promising alternative is the use of serious games, and no specific research has been found on the use of video games for the development of emotional regulation in individuals with intellectual disabilities. This article presents the first part of the design of a video game aimed at supporting the emotional regulation of individuals with intellectual disabilities, with the goal of providing an innovative and effective tool in this field.

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Keywords:serious video games, emotional regulation, intellectual disabilities

Abstract. La regulación emocional es una habilidad fundamental para el desarrollo cognitivo, social, conductual y académico de las personas con discapacidad intelectual. Sin embargo, estas personas a menudo enfrentan desafíos significativos en esta área. Se han diseñado intervenciones terapéuticas para mejorar la regulación emocional. No obstante, la mayoría de las intervenciones y estudios se han dirigido a otras poblaciones, como individuos con trastorno del espectro autista o TDAH. Algunas de ellas han demostrado ser efectivas para apoyar a personas con discapacidad intelectual, pero una alternativa prometedora es el uso de videojuegos serios, y no se ha encontrado investigación específica sobre el uso de videojuegos para el desarrollo de la regulación emocional en personas con discapacidad intelectual. Este artículo presenta la primera parte del diseño de un videojuego dirigido a apoyar la regulación emocional de personas con discapacidad intelectual, con el objetivo de proporcionar una herramienta innovadora y efectiva en este campo.

Keywords: videojuegos serios, regulación emocional, discapacidad intelectual.

1 Introduction

According to the American Psychiatric Association, intellectual disability is a disorder that begins during the developmental period of an individual. It includes limitations in intellectual functioning and adaptive behavior. Intellectual disability is classified into four levels: mild, moderate, severe, and profound, each presenting different characteristics in the conceptual, social, and practical domains [1]. Among the main characteristics of people with intellectual disabilities are delayed speech and self-care skills acquisition, limited vocabulary, short attention spans, limited initiative, delayed cognitive acquisitions, academic learning deficiencies, and social and emotional maladjustment [1] [2] [3]. Specifically, among the emotional characteristics of this population, they present difficulties in emotion recognition, lack of self-motivation, understanding the causes and consequences of emotions and self-control, inhibition, and emotion regulation [3] [4]. Emotion regulation is the ability to manage our own emotions appropriately. This is achieved by being aware of the relationship among emotion, cognition, and behavior, having appropriate coping strategies, and the ability to generate positive emotions autonomously [5]. It is important for individuals with intellectual disabilities to learn how to regulate their emotions properly. This represents a significant milestone in their cognitive development and an important achievement associated with social, behavioral, and academic competencies [6] [7]. In order to have adequate emotion regulation, individuals must first develop emotional awareness; which is the ability to be aware of their own emotions and the emotions of others. This includes the ability to identify their own emotions through the use of appropriate emotional vocabulary and the ability to perceive emotions in specific contexts [8]. Later, individuals develop emotional regulation in two phases: co-regulation and self-regulation [9] [7]. Co-regulation occurs when parents or caregivers support their children's emotional development through motivational or emotional scaffolding, as well as using some strategies for regulating emotions. Self-regulation is when the individual learns to control his/her behavior, emotions, and thoughts to achieve a goal on their own. There are some therapeutic interventions for emotional regulation applied to individuals with intellectual disabilities, such as mindfulness and dance/movement therapy. Both interventions have shown positive effects on stress management and the improvement of various emotional aspects in this population [12] [13].

An alternative to enhance emotional regulation interventions is interactive technology, such as serious video games. Serious video games are designed with the aim of educating, training, or modifying some behavior in the player while having fun [14]. In the literature, various studies have shown that the use of serious games can support the development of different skills (e.g. literacy [15]) in individuals with intellectual disabilities; however, no work has been found focused on supporting emotional regulation in this population [16]. Therefore, this study aims to design a serious video game that supports emotional regulation in individuals with intellectual disabilities.

2 Related work

In the literature, several works support the development of different abilities in people with intellectual disabilities; some of them are presented below:

2.1 Technology for individuals with intellectual disabilities

STOMP is a system based on an interactive floor that allows users to interact with digital environments using sensors integrated into a carpet on the floor [17]. This system demonstrated that individuals with intellectual disabilities can participate in various problem-solving activities and overcome challenges using this technology. On the other hand, VirtualMath is a serious virtual reality game designed to support the teaching of logical-mathematical concepts to students with intellectual disabilities [18]. VirtualMath was evaluated with students with intellectual disabilities, and the results indicated that it contributes to the development of mathematical reasoning in this population. These works have demonstrated that there is evidence that

interactive technology can support the development of different skills in individuals with intellectual disabilities.

2.2 Technology to support emotional regulation of individuals with intellectual disabilities

Several studies have been developed with the aim of supporting the development of emotion regulation skills, such as emotional awareness and emotion regulation, in diverse populations. Most of these works focus on supporting individuals with Autism Spectrum Disorder (ASD), and a few of those support people with Attention Deficit Hyperactivity Disorder (ADHD) and individuals with intellectual disabilities. Among the works aimed at supporting emotional awareness in individuals with intellectual disabilities is Emotion4Down, a serious video game designed to support the teaching of emotion recognition in people with Down syndrome and/or intellectual disabilities [19]. This video game does not present an evaluation of its usefulness or effectiveness in teaching emotions. However, it was evaluated in terms of its design, involving seven people with intellectual disabilities. The results indicated some changes in the design characteristics and data collection instruments.

On the other hand, the work of Zheng and Motti [20]presents a wearable application to support the emotion regulation of individuals with developmental disabilities. In this sense, the literature indicates that ASD, ADHD, and intellectual disabilities are grouped under developmental disabilities [21]. The aim of this work is to explore how the use of smartwatches can support the process of emotional self-regulation in individuals with developmental disabilities within the classroom. The system was evaluated with five students with developmental disabilities. The results showed that the system should add more functionalities to allow students to be more independent.

These works aimed at supporting emotional awareness and emotion regulation demonstrated that only a few studies focus on using interactive technology to support these skills in individuals with intellectual disabilities.

3 Methods

3.1 Data collection

We conducted a contextual study in two centers that provide education and therapies to individuals with intellectual disabilities and one center where psychologists, teaching assistants for special needs and babysitters collaborated. We carried out seven sessions of non-participatory observation during scholarly and therapeutic activities involving individuals with intellectual disabilities (Figure 1). Additionally, we conducted twelve structured interviews with special education teachers, psychologists, babysitters, shadow teachers, and teaching assistants for special needs. The goal of the observation sessions and interviews was to understand the characteristics of individuals with intellectual disabilities and the educational and therapeutic activities that are carried out to support their emotion regulation. Finally, we conducted five technology testing sessions with five students with intellectual disabilities to explore the use of different technologies and identify which characteristics of existing technology are appropriate for this population.

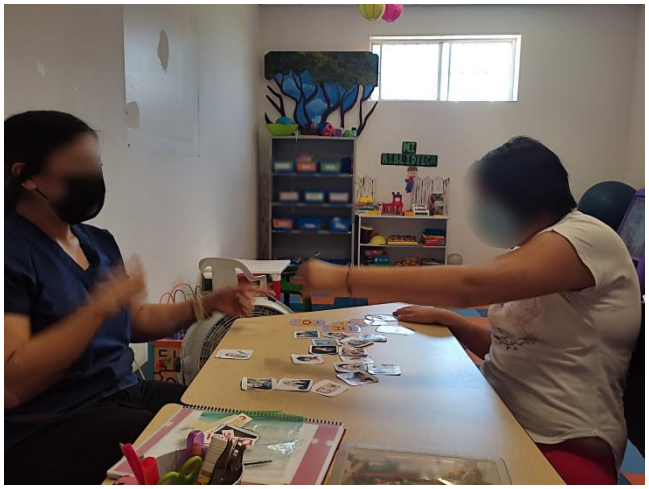


Fig. 1: Non-participatory observation session.

3.2 Data analysis

The interviews, observation sessions, and technology testing sessions were transcribed and analyzed using grounded theory techniques. Subsequently, we created an affinity diagram to organize the themes resulting from the qualitative analysis. Based on the results obtained during the analysis, we used the persona technique to describe the different user types we found in the contextual study.

3.3 Design session

To discuss the results obtained from the data analysis collected during the contextual study and obtain design proposals for video games to support the emotional regulation of individuals with intellectual disabilities, we conducted a design session with two human-computer interaction (HCI) experts. The methodology followed in this session consisted of three stages:

-Stage 1) Introduction: A brief introduction was provided about the problem being addressed and the preliminary results obtained during the data analysis process.
-Stage 2) Discussion of the proposed scenarios: In this stage, we presented the proposed scenarios that emerged from the previous stage's results to discuss their pros and cons.
-Stage 3) Discussion of the preliminary characteristics of the video game: Finally, we discuss with the experts the emotions and coping strategies that could be implemented in the video game.

4 Results

4.1 Non-technology use case scenario

As a result of the data analysis process, we obtained some scenarios that show how therapeutic activities are carried out to support the emotional regulation of people with intellectual disabilities in the centers where they receive education. Below is one of these scenarios illustrating some of the challenges of these sessions:
Karla works in a center that educates people with intellectual disabilities. Every day, she works individually with each student to reinforce their areas of need. One of her students is Pedro, with whom she works on emotions. During the session, Karla uses cards with faces that express emotions. Karla takes a card, shows it to Pedro, makes facial expressions of emotion, and verbally describes it. After showing him all the emotions, Pedro then has to identify the emotions himself.

Next, Karla shows him videos of everyday situations for Pedro to identify the emotions in each situation. Finally, she teaches him coping strategies, such as breathing. Sometimes, Pedro loses focus on the activity and prefers to play, so Karla gives him a moment to distract

himself before resuming the activity. At the end of the session, Karla congratulates Pedro on his good work and lets him play with his favorite toys for a few minutes.

4.2 Preliminary Design Characteristics

Once the previous scenario was discussed with the HCI experts, the design session resulted in the following initial design characteristics for a video game to support the therapeutic interventions of emotion regulation of individuals with intellectual disabilities.

-DC1: Customization: People with intellectual disabilities have diverse characteristics and needs, so the activities they perform to develop different skills must be customized. To address this, the video game should include a module that allows the special education teacher or therapist to customize emotions, stages, rewards, and coping strategies used during the game activities.

-DC2: Stages: During emotional regulation therapies, therapists conduct activities focused on emotion recognition and encourage the learning of coping strategies as part of the emotion regulation process. Therefore, the video game should incorporate stages for emotional awareness (emotion recognition) and emotion regulation.

-DC3: Reinforcers: One strategy employed by therapists and special education teachers to maintain the motivation of individuals with intellectual disabilities during activities is the use of positive reinforcement. An essential feature to implement in the video game is to provide positive reinforcement immediately after the player completes an activity and at the end of all activities previously programmed by the therapist.

-DC4: Interaction model: As a result of the technology testing sessions, we observed that motion-based video games can maintain the motivation and attention of individuals with intellectual disabilities. Additionally, other technologies could enable users to provide feedback to the system, providing information about their activities. This would allow for a record of their progress during video game usage sessions,

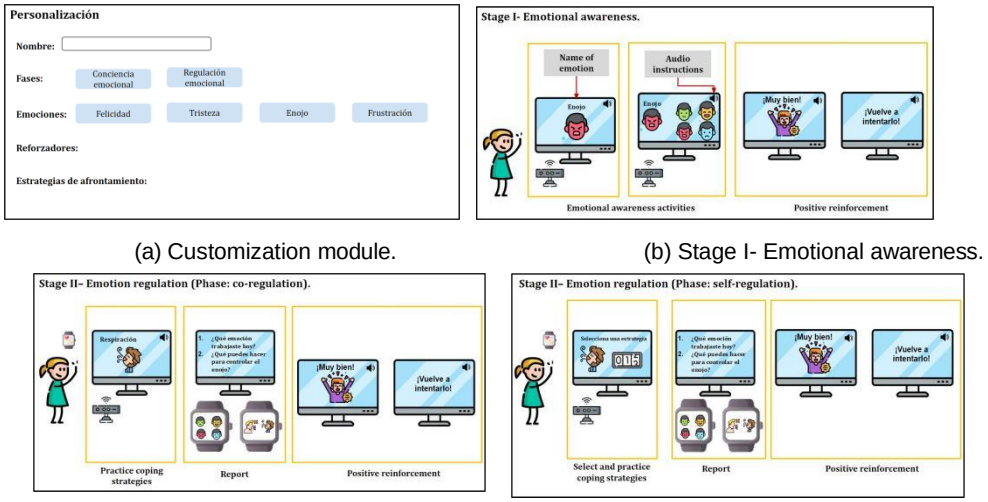
-DC5: Instructions: The instructions of the video game should be verbal, brief, direct, and through examples.

-DC6: Emotions: According to specialists, anger and frustration are some of the most challenging emotions for individuals with intellectual disabilities to manage. However, other emotions, such as sadness and happiness, can also present difficulties.

4.3 The Video game

We developed a low-fidelity prototype based on the initial design characteristics proposed by HCI experts. The interaction model relies on movement (DC4), and the activities are divided into two stages: emotional awareness and emotional regulation (DC2). Therapists will be able to customize some features of the video game according to the player's needs and preferences (DC1), such as name, stage to work on, emotions, reinforcements, and coping strategies (Figure 2a).

Additionally, the video game will allow the practice of four emotions: happiness, sadness, anger, and frustration (DC6).



(a) Customization module.

(b) Stage I- Emotional awareness.

(c) Stage II- Emotion regulation (Phase: Co-tion (Phase: regulation).

(d) Stage II- Emotion regula-Self-regulation).

Fig. 2: Low-fidelity prototype from the preliminary design characteristics.

The goal of the emotional awareness activities is to support the recognition of these four emotions in faces and everyday situations (Figure 2b). Subsequently, during the emotional regulation stage, the user will engage in emotional
co-regulation, practicing coping strategies previously defined by the therapist. The user will then complete a report detailing the emotion they worked on and how it can be managed. This report will be completed using a smartwatch connected to the video game to store gathered information, which the therapist can later review (Figure 2c). Finally, in the second part of this stage, during the emotional
self-regulation phase, the user will be able to select, based on their own criteria, the coping strategy they consider appropriate for the emotion they are working on. (Figure 2d)
Instructions throughout all activities will be brief and provided in audio format (DC5). After all activities the therapist schedules, the player will receive a final reward composed of the partial rewards earned during the game (DC3).
Referring to the non-technology use case scenario described in the section 4.1, the following shows how the proposed video game can support emotional regulation interventions for people with intellectual disabilities:

Karla works in a center that provides education for people with intellectual disabilities. Every day, she works individually with each student to reinforce their areas of need. One of her students is Pedro, with whom she works on emotions. During the session, Karla personalizes the video game with the name of the student, the phase, and the emotions to work on (happiness, sadness, anger, or frustration) (DC6), as well as the reinforcers to be presented (DC1). During the activities, the videogame's audio instructs Pedro to identify different emotions and select the images that express them (DC5). When Pedro selects the correct answer, the videogame congratulates him. If Pedro selects an incorrect image, he is asked to try again (DC3). When Karla observes that Pedro performs the activities correctly, she moves on to the emotional regulation phase (DC2). Karla customizes the game for Pedro to practice the coping strategies she selects (DC1). At the start of the game, Pedro has to mimic the game character's exercise while the game tracks his movements to determine if he performs them correctly (DC4). Then, using a smartwatch, Pedro answers some questions about the exercise (DC4). Once Karla observes that Pedro performs the exercises correctly, she personalizes the game again so that he can choose the coping strategy he wants to practice. Throughout the session, Pedro is motivated to complete all the activities. At the end of the session, Karla congratulates the student on his good work, and they return to their academic group activities

5 Conclusion and future work

This paper presented the results of the first design session to design a video game to support the emotional regulation of individuals with intellectual disabilities. We conducted a contextual study involving psychologists, special education teachers, babysitters, and individuals with intellectual disabilities. The results of the contextual study indicated that individuals with intellectual disabilities often struggle to regulate their emotions. Individuals with intellectual disabilities must learn to regulate their emotions properly because this represents a significant milestone in their cognitive development and the achievement of an independent life. Currently, we are conducting design sessions with special education teachers to discuss the preliminary design features resulting from the session with the HCI experts and to generate new proposals for the video game design to support emotional regulation in individuals with intellectual disabilities. Once the design sessions are completed, the high-fidelity prototype will be implemented, and formative evaluations will be carried out with the participation of people with intellectual disabilities to validate the design features and evaluate the video game's usability. Subsequently, we plan to conduct summative evaluations to investigate its impact in the emotional regulation of individuals with intellectual disabilities.

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ESPECIAL

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Silabateando: Aplicación móvil para la enseñanza lúdica de lectoescritura en niños con TEA que asisten al Aula Bambú del ITSX

Silabateando: Mobile application for the playful teaching of reading and writing in children with ASD who attend the Bamboo Classroom of the ITSX

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Resumen: El presente estudio tiene como fin fomentar el desarrollo de la lectoescritura en niños con Trastorno del Espectro Autista (TEA). El análisis de requisitos se hizo de manera documental para revisar los aspectos importantes del TEA; se identificaron las características de la enseñanza alfabética y silábica para niños de edades comprendidas de 3 a 8 años con apoyo de especialistas del Instituto de Investigaciones Cerebrales de la Universidad Veracruzana. Finalmente, se diseñó un prototipo lúdico denominado SilabaTEAndo, con elementos que captan la atención del infante y que pueda aprender de manera divertida a través de juegos. Dicha app complementa la enseñanza alfabética y silábica, a través de la emisión de los sonidos de las letras y sílabas, así como con la asociación de las palabras con su respectiva imagen. El alcance del proyecto se limita al Aula Bambú del Instituto Tecnológico Superior de Xalapa y a los niños con TEA que asisten a esta institución en busca de mejorar sus habilidades de lectoescritura.

Palabras clave: Trastorno del espectro autista, Enseñanza de la lectoescritura, Aplicaciones móviles, Recursos lúdicos.

Abstract: The purpose of this study is to promote the development of reading and writing in children with Autism Spectrum Disorder (ASD). The requirements analysis was carried out in a documentary manner to review the important aspects of ASD; the characteristics of alphabetic and syllabic teaching for children aged 3 to 8 years were identified with the support of specialists from the Brain Research Institute of the University of Veracruz. Finally, a playful prototype called SilabaTEAndo was designed, with elements that capture the attention of the infant and that he can learn in a fun way through games. This app complements alphabetic and syllabic teaching, through the emission of the sounds of letters and syllables, as well as with the association of words with their respective image. The scope of the project is limited to the Bamboo Classroom of the Higher Technological Institute of Xalapa and to the children with ASD who attend this institution in search of improving their reading and writing skills.

Keywords: Autism spectrum disorder, Literacy teaching, Mobile applications, Playful resources.

1 Introducción

El trastorno del espectro autista (TEA), es una condición que afecta el desarrollo neurológico y se caracteriza por dificultades en la comunicación social, así como patrones de comportamiento e intereses restringidos y repetitivos [1]. Desde 1963, Samuel Kirk, lo asocia al término “Learning Disabilities” en español “Dificultades de aprendizaje”, concepto que es capaz de englobar alteraciones o retrasos en el desarrollo de uno o más de los procesos de lenguaje, habla, deletreo, escritura, trastorno de conducta, entre otros [2]

Este trastorno presenta una amplia variabilidad en su manifestación y puede afectar a las personas de diferentes maneras y en diversos grados [3]. Según la Organización Mundial de la Salud (OMS), existen más de 90 millones de personas en el mundo con TEA, considerando que uno de cada 160 nacimientos son personas con autismo [4]. Específicamente, en México, uno de cada 115 niños tiene autismo [5].
A pesar de los avances en el tratamiento de dicho trastorno y de la diversidad de herramientas educativas que abordan las necesidades de estos niños, la enseñanza de habilidades básicas como la lectoescritura sigue representando un desafío considerable para padres y docentes.
En este contexto, el Aula Bambú del Instituto Tecnológico Superior de Xalapa (ITSX), es un espacio físico diseñado específicamente para trabajar con tecnología asistida para apoyar el aprendizaje, la comunicación y la autonomía de niños con autismo. Este proyecto fue diseñado por estudiantes del ITSX e impulsado por el cuerpo académico Ingeniería e Innovación Sustentable en colaboración con especialistas del Insti- tuto de Investigaciones Cerebrales de la Universidad Veracruzana (UV). Durante su construcción, se identificó la necesidad de crear soluciones educativas innovadoras, entre las que predomina la enseñanza de la lectoescritura a niños de edades tempranas, mediante la generación de recursos lúdicos mediados por la tecnología que capten su interés y faciliten su aprendizaje dentro del aula Bambú.
Dado lo anterior, este estudio tiene como objetivo describir el desarrollo de una aplicación móvil (App) denominada SilabaTEAndo, la cual apoya el aprendizaje de la lectoescritura en niños con TEA. De manera específica, se describe el proceso mediante el cual se llevó a cabo el análisis de requerimientos, así como la implementación del prototipo lúdico que facilita la enseñanza del alfabeto y la formación de palabras mediante sílabas.

2 Metodología

El estudio trata de un enfoque mixto, ya que combina el análisis de información cuantitativa obtenida a través de encuestas y de una investigación cualitativa derivada del análisis documental relacionado con el proceso de lectoescritura y con los métodos de enseñanza a utilizar con los niños con TEA. Posteriormente, se hace una exploración de diversas aplicaciones móviles con el mismo giro, a fin de identificar las áreas de oportunidad que permitan desarrollar una aplicación competitiva. Finalmente, se hace una investigación de campo, la cual ha permitido entablar conversaciones con padres y tutores de niños con TEA.

2.1 Encuesta

Se aplicó una encuesta mediante Google Forms a un total de 120 personas de la ciudad de Xalapa de manera virtual con el propósito de recopilar datos sobre el autismo (TEA) y el uso de aplicaciones móviles para ayudar a los niños a leer.

2.2 Análisis documental

Uno de los propósitos de este proyecto radica en el mejoramiento de una de las competencias fundamentales para el desarrollo humano: la lectura y escritura, especialmente en el contexto de niños con TEA. Por lo tanto, se abordan las características de estas habilidades.
La lectoescritura es un proceso complejo que implica la interacción entre la comprensión lectora y la producción escrita. La lectura implica dos habilidades esenciales: la decodificación y el

La decodificación consiste en convertir símbolos escritos en sonidos, mientras que el reconocimiento de palabras consiste en identificar palabras completas en función de su forma escrita [6]. Por otro lado, la escritura implica la producción de texto de forma estructurada, clara y coherente, lo cual requiere la utilización de múltiples dominios y la apropiación de los principios del sistema alfabético [7].
Los métodos de enseñanza son los planteamientos y tácticas empleados para transmitir conocimientos, capacidades y principios a los estudiantes. Éstos, pueden ser muy variados y se pueden clasificar de diferentes maneras [8]. El desarrollo de esta aplicación se basa en la combinación de los siguientes métodos:
a) Deletreo de palabras: considerado uno de los más antiguos que fomenta la lectura a través del deletreo. Por ejemplo, la palabra "mamá" se deletrea como "eme-a-eme-a". Con éste, se comienza enseñando los nombres de las letras del alfabeto, empezando por las vocales y luego las consonantes [9].
b) Fonético: basado en los sonidos y sus letras representativas. Éste se dedica a enseñar a los niños a que puedan identificar y poder pronunciar los sonidos de las letras y así poder posteriormente convertirlos en palabras lo que les permite aprender a leer con fluidez y a comprender lo que leen [10].
c) Silábico: consiste en la enseñanza de las vocales que se van combinando con las consonantes formando silabas y luego palabras posteriormente se construyen oraciones [11].
d) Global: enfocado en favorecer la adquisición de habilidades específicas, como la lectura y escritura, a través de la comprensión de contextos generales en lugar de únicamente centrarse en habilidades de memorización y decodificación, se apoya en el uso de imágenes [12].

2.3 Exploración de trabajos relacionados

Actualmente existen múltiples aplicaciones para complementar la educación de los niños con TEA, por lo que en la tabla 1 se muestran algunas de éstas.

Tabla 1 Aplicaciones móviles lúdicas utilizadas para la educación de niños con TEA.

Nombre de la App	Descripción
LEA (Lectoescritura para Autismo) 	Aplicación desarrollada por estudiantes del Instituto de Investigaciones Cerebrales de la UV, para lograr que los niños incrementen sus habilidades motoras y cognitivas a través de la estimulación de forma virtual. Cuenta con ocho secciones: Mi Familia, Mi Cuerpo, Mis Sentimientos, ABC, Escribo, Leo, Juego y una sección adicional para aprender a usar el dispositivo. Cada ejercicio permite la formación de palabras mediante la manipulación de elementos y un teclado digital [13].
Leo con Lula 	Aplicación desarrollada para un sistema operativo iOS, la cual consiste en enseñar por medio del método de enseñanza global mediante el uso de tecnologías para que personas con TEA pue dan aprender a leer de manera didáctica. No cuenta con un criterio de edad, pues cualquier niño que comprenda el proceso puede utilizarla [14].
MITA 	Se enfoca en actividades interactivas y cautivadoras diseñadas para mejorar la capacidad de los niños para integrar mentalmente múltiples objetos [15].
Yo también LEO 	Esta aplicación se basa en el método de aprendizaje global, la cual permite adaptarse a las necesidades de estos niños con el propósito de potenciar sus capacidades motoras. Busca fomentar la autonomía y aumenta la motivación [16].

A diferencia de las aplicaciones mostradas en la tabla anterior, la aplicación que aquí se propone denominada Silabateando, se enfoca exclusivamente a la enseñanza de lectoescritura por medio del método silábico, dirigido a un público infantil. Además, tras la asesoría de expertos sobre las necesidades de un niño con TEA, asociados a este proyecto, se determinaron, cuestiones básicas como los colores a utilizar, el diseño de las ilustraciones, el audio para captar la atención del niño, los niveles de dificultad ajustables a su aprendizaje, así como un sistema de recompensas para motivarlo.

2.4 Investigación de campo

Para el desarrollo de esta investigación fue necesario acudir al Aula Bambú y realizar las entrevistas a padres de familia, así como aplicar los instrumentos con apoyo de los especialistas con el fin de evaluar el uso de la aplicación móvil con niños neurotípicos y con TEA. El procedimiento utilizado para llevar a cabo la investigación de campo se muestra en la Fig. 1

Figura 1 Pasos para la realización de la investigación de campo.

Por consiguiente, el enfoque de esta investigación se centra en el diseño y desarrollo de una aplicación que satisfaga los requerimientos de los niños con TEA en cuanto al aprendizaje de la lectoescritura.
La información recolectada a partir de los distintos instrumentos ha sido esencial para la comprensión y evaluación de la problemática y ha permitido la identificación de una alternativa de solución adaptada a las necesidades de los niños con TEA y sus familias, mismos que se especifican en la sección siguiente.

2.5 Diseño de casos de uso y escenarios

Para la programación y construcción de la aplicación, se utilizó ICONIX, la cual permitió la comprensión de los requerimientos a partir de modelos UML y un enfoque iterativo. La visualización de las necesidades de los usuarios, se hicieron a través de diagramas de casos de uso, de los cuales se ejemplifica con el diseñado en la Fig. 2, así como su escenario correspondiente en la Tabla 2; ambos fueron utilizados posterior- mente para la elaboración de las interfaces respectivas.

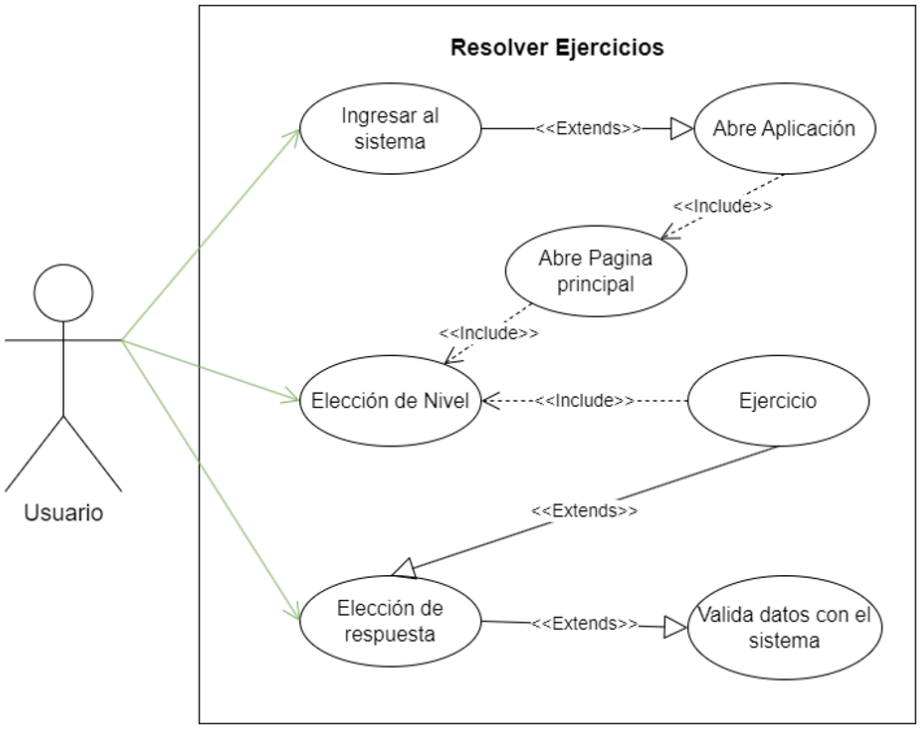

Fig. 2. Caso de uso para la interacción principal con la aplicación.

El escenario que describe el caso de uso anterior se muestra en la Tabla 2.

Caso de Uso	**Resolver Ejercicio**	
Objetivo	Lograr resolver los ejercicios que plantea cada nivel.	
Descripción	Este caso de uso define la manera de que el usuario realiza los ejercicios correspondientes a cada nivel.	
Actores	Usuario	
Precondiciones	El usuario debió haber iniciado sesión, encontrarse en la pantalla principal.	
Flujo principal	Usuario 1.- Clic a “Nivel #”. 4.- Clic a su respuesta. 5.- Clic a Aceptar. 8.- Clic a Siguiente.	Sistema 2.- Sistema abre ventana del nivel. 3.- Sistema muestra ejercicio con su audio correspondiente. 6.- El sistema valida que la opción sea la correcta. 7.- Sistema despliega ventana de felicitaciones. 9.- Repite desde paso 3.
Flujo alternativo	1.- El sistema muestra mensaje “¡Ups! Vuelve a intentarlo”. 2.- Repite desde paso 4.	
Postcondición	Se concluye con un nivel superado.	

De la combinación de los métodos de enseñanza de la lectoescritura obtenidos a través del análisis documental, se diseñaron las siguientes interfaces intuitivas (Fig. 3 y 4).

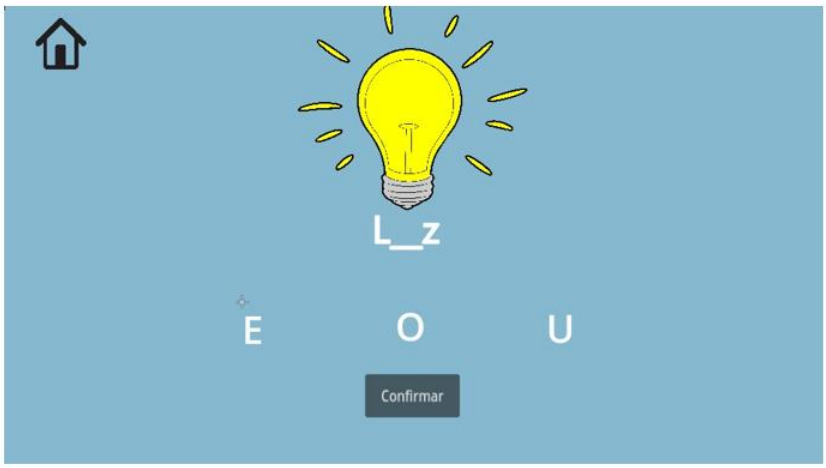

Fig. 3. Primera interfaz intuitiva y minimalista que hace uso del método de deletreo, fonético, silábico y global.

Fig. 4. Segunda interfaz intuitiva y minimalista que hace uso del método de deletreo, fonético y silábico.

3 Resultados

Como se mencionó anteriormente, se llevó a cabo una encuesta donde participaron 139 personas, entre los cuales se encuentran padres de familia, tutores y personas cercanas a niños con TEA. Los datos obtenidos a partir de la aplicación de los diversos instrumentos de recolección fueron: Según la encuesta, el 89,2% de los encuestados saben qué es el TEA (Fig. 5), y el 90,8% (Fig. 6), conoce a alguien con TEA, lo que un alto nivel de conciencia y familiaridad con el TEA en los encuestados.

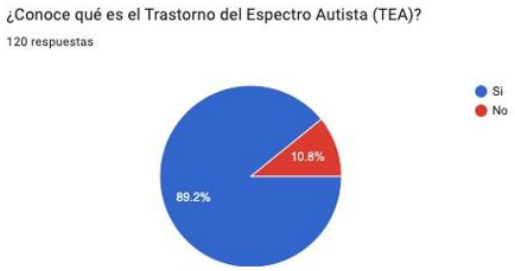

Fig. 5. Gráfico del conocimiento de las personas encuestadas acerca del TEA.

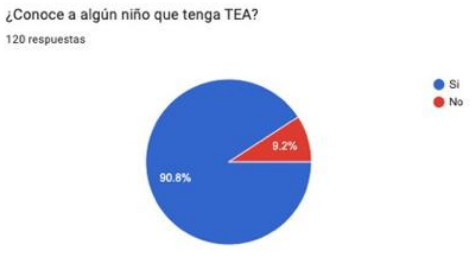

Fig. 6. Gráfico del conocimiento de personas que posean TEA.

El 84,2% de los encuestados tienen dificultad para comunicarse (Fig. 7) y el 50% tiene dificultades para leer, además del 30% que no sabe leer (Fig. 8), lo que es consistente con el hecho de que el TEA a menudo se asocia con dificultades en la comunicación, la lectoescritura y la interacción social.

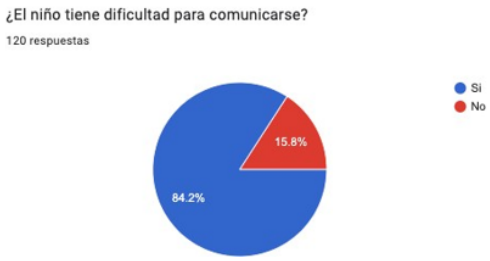

Fig. 7. Gráfico de la dificultad de comunicación en la muestra de niños con TEA.

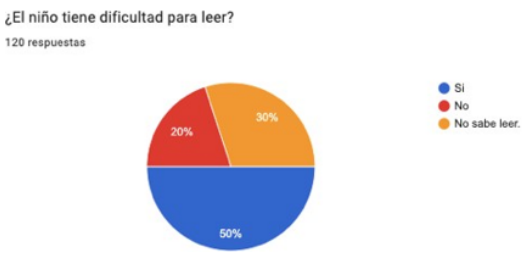

Fig. 8. Gráfico de la dificultad de los niños con TEA para leer

La información obtenida fue de gran utilidad para diseñar la aplicación móvil que aquí se describe, misma que se enfoca en facilitar la lectura en niños con TEA. Adicional- mente, se tomaron en cuanta otros parámetros resultantes de la encuesta, como los colores que le agradan o desagradan y los métodos que utiliza para el complemento de su aprendizaje. Por lo tanto, la aplicación debe ser accesible y fácil de usar, lo que podría significar incluir opciones para la comunicación no verbal o para una navegación intuitiva.

4 Conclusiones

La implementación de aplicaciones móviles para niños con TEA, presentan diversos retos para sus desarrolladores. Entre éstos podemos mencionar 1) adaptabilidad a las necesidades individuales, mejorando así su experiencia de aprendizaje; 2) interacción activa que puede mejorar la capacidad de aprendizaje de los niños; 3) accesibilidad con el fin de que su diseño sea fácilmente utilizado y comprendido; 4) flexibilidad, para que las aplicaciones puedan usarse en cualquier momento y lugar.
Los instrumentos de recopilación de datos, como encuestas y entrevistas con padres, tutores y docentes, proporcionaron información valiosa sobre las necesidades y preferencias de los usuarios finales. Esto permitió ajustar el diseño y las funcionalidades de la aplicación para que fueran realmente útiles y accesibles para los niños con TEA.
El análisis documental y el benchmarking permitieron diseñar e implementar una App que combina algunos de los diferentes métodos de lectoescritura propuestos por expertos, facilitando la identificación y definición clara de los requisitos del sistema.
La utilización de casos de uso y escenarios en el desarrollo de sistemas ofrece ven- tajas tales como facilitar la comunicación entre desarrolladores y stakeholders, definir de manera clara los requisitos y centrarse en las necesidades de los usuarios.

Las pruebas del primer prototipo permitieron obtener retroalimentación de los expertos del Instituto de Investigaciones Cerebrales de la Universidad Veracruzana (UV), antes de realizar pruebas con los niños que poseen TEA y que asisten al aula Bambú. Sus observaciones permitieron mejorar significativamente tanto las funcionalidades orientadas a la enseñanza de las habilidades de lectoescritura, como el diseño de la interfaz de la App, en lo referente al uso de colores, de ilustraciones que no funcionen como distractores, al tipo de voz agradable para la creación de audios y al manejo de recompensas para fomentar la motivación.
Finalmente, ya que toda aplicación tiende a evolucionar conforme a las necesidades de los usuarios, Silabateando no es la excepción. Esta herramienta continuará adaptándose para responder a los diversos casos que se presentan en el espectro autista, ya que, por sus particularidades, puede requerirse de funciones adicionales o personalizadas.

5 Agradecimientos

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