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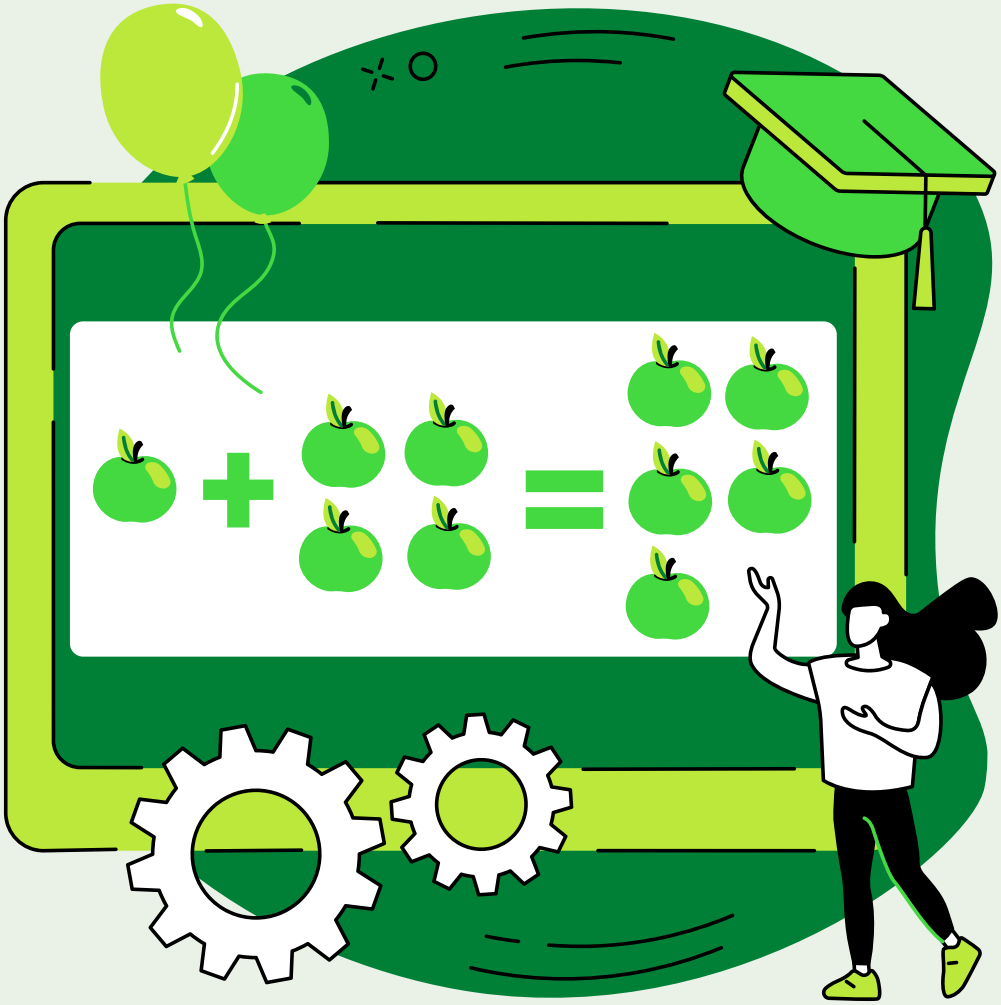

CONCEPTUALIZACIÓN TEÓRICO-METODOLÓGICA PARA LA INTRODUCCIÓN DE LA GAMIFICACIÓN EN EL DESARROLLO DE LAS COMPETENCIAS STEAM EN LA EDUCACIÓN SUPERIOR. CASO: UNIVERSIDAD ECOTEC

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INFORME RAZONADO DEL/DE LOS DIRECTOR/ES DE LA TESIS
(se hará mención de la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma).

La doctoranda (Johanna Andrea Navarro Espinosa) ha progresado enormemente como investigador desde que comenzara la tesis doctoral en diciembre de 2019 en la Universidad de Córdoba. Durante estos años el doctorando ha realizado todas las actividades obligatorias y opcionales, trabajado duro y siguiendo siempre las pautas de
trabajo que le hemos marcado los directores y el plan de investigación que se estableció. Como principales frutos del trabajo realizado se han derivado los tres siguientes artículos publicados o aceptados en revistas incluidas en los tres primeros cuartiles de la relación de revistas del ámbito de la especialidad y referenciadas en la última relación publicada por el Journal Citation Reports (SCI y/o SSCI), así como Capítulos de libro publicados por editoriales indexadas en SPI y referenciadas en WOS:

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Quiero empezar agradeciendo a Dios, por las bendiciones otorgadas a lo largo de mi vida, principalmente por la salud y las oportunidades para continuar superándome.

Realizar un doctorado era un objetivo a largo plazo. Sin embargo, en el año 2018 se cristalizó el convenio interinstitucional entre la Universidad ECOTEC y la Universidad de Córdoba (UCO), ¿era el momento?, definitivamente sabia a donde quería llegar, así que tomé la decisión de empezar a recorrer el camino que me permitiría obtener mi doctorado. Sucedieron algunas cosas que no estaban previstas en mis planes: la llegada de mi bella hija Isabella Sophia y la búsqueda de un nuevo tutor (a), situaciones que pudieron percibirse como dificultades, se convirtieron en bendiciones, porque el ¡El tiempo de Dios es perfecto!.

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Johanna Andrea Navarro Espinosa

"Somos arquitectos de nuestro propio destino"

Albert Einstein

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TESIS DOCTORAL EN COMPUTACIÓN AVANZADA, ENERGÍA Y PLASMA

RESUMEN

La presente investigación propone un modelo teórico- metodológico que engloba la incorporación de las Tecnologías de la Información y la Comunicación, TICs, y la gamificación para el desarrollo de competencias STEM en Instituciones de Educación Superior sostenibles. En la consecución de estos objetivos se realizó, en primer lugar, un estudio bibliométrico con el propósito de analizar el impacto de estas herramientas metodológicas, y en el que se manifestaron los aspectos positivos y negativos que se observan de su inclusión en la educación superior. Por otra con el análisis de resultados se proponía determinar la existencia de una tendencia creciente en la última década de modelos de implementación específicos y su adecuada implementación en las IES.

A continuación, se realizó un estudio comparativo entre Instituciones de Educación Superior (IES) en Ecuador y España, en el cual se utilizó una encuesta cualitativa previamente validada y distribuida en línea, para determinar los factores de inclusión y uso de las TICs en las IES en dos momentos cruciales de la pandemia sobrevenida en 2019, antes y después del confinamiento. Los resultados mostraron la esencialidad de las TICs para lograr IES sostenibles, destacando el beneficio de su inclusión en el proceso de enseñanza y aprendizaje y en el desarrollo de habilidades TICs en los docentes. También, se evidenció que los docentes carecían de capacitación y modelos específicos para una correcta inclusión y uso de las TICs en el aula, el cual se destacó mucho mas en docentes con mayor experiencia. Otras de los resultados obtenidos fue la relación existente entre el uso de las TICs, experiencia de los docentes, y capacitación en su uso, con el bienestar emocional de los profesionales.

El siguiente estudio cualitativo se centró en analizar la influencia de la tecnología y el Coivd-19 en docentes con alta experiencia en educación STEM en las IES. Los resultados obtenidos mostraron las dificultades presentadas por los docentes en una situación excepcional como el COVID-19 en la que el cambio en la modalidad de enseñanza, imposición de uso de tics entre otros factores, generaron altos niveles de ansiedad y estrés emocional relacionado con su percepción de la metodología de trabajo online, indistintamente del país de procedencia. También se evidenció que los docentes con mayor formación en los campos STEM y dominio de las TICs eran menos propensos a desarrollar tecnoestrés, por lo que se consideró que esta variable actuaba como un efecto preventivo.

Por ultimo se propone un modelo general STEM sostenible para las instituciones de Educación Superior, que concibe a los diferentes actores (estudiantes y docentes) y los beneficios de la inclusión y uso de las TICs en el proceso de enseñanza y aprendizaje que contribuya al desarrollo de sus habilidades tecnológicas y bienestar emocional.

ABSTRACT

This research proposes a theoretical-methodological model that conceives for the incorporation of ICT Information and Communication Technologies and gamification for the development of STEM skills in sustainable Higher Education Institutions. For this, a bibliometric was carried out with the objective of analyzing the impact of ICTs and gamification, highlighting positive and negative aspects of their inclusion in higher education, which would allow determining if there was a growing trend in the last decade or specific implementation models of ICTs. its proper implementation in HEIs.

Next, a comparative study was carried out between Higher Education Institutions (HEIs) in Ecuador and Spain, in which a qualitative survey previously validated and distributed online was obtained, to determine the factors of inclusion and use of ICT in HEIs. in two moments before and after confinement. The results showed the essentiality of ICTs to achieve sustainable HEIs, highlighting the benefit of their inclusion in the teaching and learning process and in the development of ICT skills in teachers. Also, it was evident that teachers lacked training and specific models for the correct inclusion and use of ICT in the classroom, which was much more prominent in teachers with more experience other difficulties related to emotional well-being.

In the following qualitative study, the influence of technology and Coivd-19 on teachers with high experience in STEM education in HEIs was analyzed. The results obtained showed the exhibitions presented by teachers in an exceptional situation such as COVID-19 in which the change in the teaching modality, the imposition of the use of tics, among other factors, generated high levels of anxiety and emotional stress related to their perception. of the online work methodology, regardless of the country of origin. It was also shown that teachers with more training in the STEM fields and ICT proficiency were less likely to develop technostress, which is why it is considered a preventive effect.

Finally, a general sustainable STEM model is proposed for higher education institutions, which conceives the different actors (students and teachers) and the benefits of the inclusion and use of ICTs in the teaching and learning process that already contributes to development. of their technological skills and emotional well-being.

1

INTRODUCCIÓN

Las Tecnologías de la Información y la Comunicación (TICs) son herramientas desarrolladas para gestionar, almacenar y enviar la información entre sistemas y usuarios. Estos instrumentos teórico-conceptuales representan soportes y canales que procesan, almacenan, sintetizan, recuperan y presentan información de la forma más variada (1). Es decir, son un conjunto de avances tecnológicos, posibilitados por la informática, las telecomunicaciones y las tecnologías audiovisuales, que proporcionan mecanismos para el tratamiento y la difusión de la información y canales de comunicación(2).

La era digital, iniciada en los años cincuenta, supuso el inicio del desarrollo de las TICs, aunque no fue hasta finales de los ochenta cuando éstas se empezaron a integrar en la vida cotidiana y social de la población. Las TICs, subestructuras, engranajes, widgets digitales y analógicos, han logrado una integración sin precedentes en la misma, convirtiéndose en sistemas personalizados mejorados (3). Éstas son herramientas en diferentes etapas de creación, desde los prototipos de investigación a la producción en masa (4,5). La producción masiva de tecnología y la disponibilidad de éstas ha creado variaciones en la interacción de las personas, las estructuras sociales y todos los sistemas, como son los educativos(6). Más aun, muchas nuevas tecnologías han sido creadas para realizar o facilitar las necesidades de las poblaciones [6], las cuales, han sido desarrolladas, adaptadas e integradas en diversos campos, desde la agricultura hasta los drones o la educación con entornos virtuales de aprendizaje (7,8). Estas herramientas han

transformado los contextos formales e informales, y por consiguiente, el proceso de enseñanza – aprendizaje. En este sentido, las TICs han promocionado el contexto informal donde muchos cursos abiertos en línea, conocidos con MOOCs, sobresalen por su flexible y rápido acceso.

Un sector altamente modificado por las TICs, es la educación, creando sistemas flexibles, dinámicos y sostenibles (7,9–12). En esta área, la creación e inclusión de entornos adaptables, accesibles y atractivos, utilizando inteligencia artificial o realidades virtuales están aumentando como TICs punteras, ya que permite una vida útil más larga y, por tanto, un sistema sostenible (13,14). Estos entornos usualmente son creados para teléfonos inteligentes, computadores, tablets, en función de sus características ubicuas, fáciles de usar y rápidas (15,16).

El proceso de enseñanza – aprendizaje se concibe de forma interactiva, centrada en el alumno que permite el modelo de aprendizaje TPACK (Conocimiento técnico pedagógico del contenido educativo), , El modelo TPACK, creado por Shulman, Mishra & Koehle (2006),establece que el conocimiento en general está integrado por el conocimiento del contenido (CK), el conocimiento pedagógico (PK) y el conocimiento tecnológico (TK). . Un trabajo reciente, revela que el uso compartido de las TICs en las clases magistrales fueron fundamentales en el proceso de enseñanza, teniendo en cuenta los antecedentes demográficos y económicos de los estudiantes así como la formación y el dominio de las tres dimensiones del modelo por parte de los docentes (17). Sin embargo, otros estudios de este modelo no encontraron evidencias definitivas sobre el impacto de las TICs en el proceso de aprendizaje de los estudiantes (18,19).

De acuerdo con F. Candia García (2016), la inclusión de los TICs en estudios de posgrado como innovación educativa es una realidad(17). Sin embargo, esta innovación está en peligro cuando el docente que imparte las clases magistrales no haya recibido entrenamiento sobre el contexto formal e informal de los TICs (OCDE, 2010) (20). Dichas tecnologías interactivas, promueven el aprendizaje activo de los estudiantes, permitiendo su crecimiento e independencia, y creando conexiones y colaboraciones entre otros para solucionar problemas. Estas metodologías de aprendizaje permiten la formación de competencias, apoyándose en la clase magistral (10,12).

El elemento más poderoso que fortalece las TICs es Internet, configurando la denominada Sociedad de la Información. Es decir, un sistema social reglado por el intercambio de datos entre los miembros de dicho grupo social en un entorno virtual. Por lo tanto, el uso de las TICs ha producido una variación notable en la interacción de las estructuras sociales, un cambio en la educación, en las relaciones interpersonales y en la forma de difundir y generar conocimientos. Dentro del campo de la educación, las TICs han propiciado la creación de redes de conocimiento que se han mostrado claves para el desarrollo y creación de nuevas tecnologías aplicadas al ámbito educativo (21). Así mismo, se comprueba que aportan elementos de mejoras en el proceso de enseñanza-aprendizaje (22) por lo que se hace necesario llevar a cabo un análisis permanente de la vinculación entre la educación y las TICs, para poder realizar aportes desde un punto de vista académico y al fortalecimiento de la educación como un derecho humano.

Como característica destacable, se observa que las TICs permiten crear procesos innovadores, mejorar servicios y fortalecer las estrategias didácticas en el aula (23) en donde gracias a la ubicuidad han aumentado el uso de los dispositivos móviles por parte de los estudiantes y docentes que exploran nuevas posibilidades didácticas con la inclusión de estos recursos (24) .Las TICs también han permitido la introducción de nuevas modalidades de enseñanza, mejorando las posibilidades de la educación virtual gracias a que en el contexto formal transforman los procesos de enseñanza- aprendizaje centrados en el estudiante y en los contextos informales, brindan la oportunidad de ampliar la información a través de cursos online gratuitos (MOOCS) y espacios de aprendizaje personal (PLE) (25) ; estos últimos, basados en un modelo de aprendizaje horizontal en donde sus miembros son motivados por la investigación y el conocimiento (26).

Los cambios en las prácticas didácticas atribuibles a la integración de las TICs en el aula han sido escasos hasta el año 2019, en que estas experiencias, aunque eran innovadoras y creativas, dependían de la voluntariedad del profesorado y el alumnado. En estos cambios didácticos subyacen una serie de ideas y enfoques pedagógicos comunes que pretenden aprovechar todo el potencial de las TICs, enmarcadas en una nueva cultura del aprendizaje. Estas son lo que los autores denominan pedagogías emergentes (27). Las pedagogías emergentes tienen gran protagonismo a través del aprendizaje continuo y uso de recursos educativos abiertos, que promueven y fomentan el pensamiento crítico, creativo e independiente de los estudiantes; y además, propician la implementación de metodologías activas como el *desing thinking* conocido como el pensamiento de diseño o el *flipped learning,* que se centra en la inversion del proceso de aprendizaje mediante el uso de videos. Específicamente el *design thinking* se centra en la generación de ideas de diseño para resolución de problemas, de hecho, este módelo pedagógico se basa en identificar los problemas individuales del alumnado con el fin de satisfacer sus necesidades de aprendizaje activo mediante un sistema de simbiosis entre los alumnos/as y el profesorado. El *flipped learning* hace uso de un sistema de grabación de los temas, realizados por el profesorado, que implica un aprendizaje previo del alumnado fuera del aula; siendo ésta utilizada para la resolución de problemas y adecuación de la metodología de aprendizaje a las necesidades del alumnado

Estas pedagogías emergentes, con un marcado carácter integrador, dan lugar a modelos educativos innovadores, los cuales deben fomentar ambientes de aprendizaje interactivos, sincrónicos y asincrónicos donde el docente se encuentra comprometido con el aprendizaje de sus alumnos. El profesorado por tanto cumple el rol de asesor y guía, y los estudiantes se convierten en actores de cambio con habilidades y modos de trabajo innovadores en los cuales utilizan tecnologías de vanguardia, materiales didácticos, recursos de información y contenidos digitales(28).

Dentro de todas estas metodologías emergentes destaca la gamificación, que se centra en la enseñanza mediante juegos, y uso de redes sociales, las cuales contribuyen al desarrollo de competencias como resolución de problemas, autonomía y apoyo a estilos de aprendizaje a través del juego y en red (29). En una sociedad digitalmente conectada y con libre acceso a la

información, capaz de sintetizar y generar nuevos conocimientos, que requiere más elementos de motivación seguir conectados,la gamificació favorece el proceso formativo a través una estructura con acciones establecidas y manteniendo un alta motivación en los estudiantes(30). Entre los efectos positivos del uso de la gamificación predomina la motivación y satisfación de los alumnos, lo que contribuye al bienestar emocional y la salud mental de éstos, así como una mejora de su rendimiento (31,32).

Algunas de las limitaciones en la inclusión de las TICs y que ha dado origen a diversas investigaciones es la actitud y percepción de los docentes en relación a la incidencia de las TICs en el proceso de enseñanza-aprendizaje, falencias en el desarrollo de las competencias digitales (21) y conocimientos pedagógicos que le permita identificar su uso para una adecuada implementación(22), se considera uno de los factores determinantes para su integración y uso en contextos educativos (33).

La propuesta metodológica para operar estos modelos educativos es el denominado Ambiente Virtual de Aprendizaje (AVA) (34), en el que se requiere que quienes participan en el diseño de estos ambientes deben conocer todos los recursos tecnológicos disponibles (infraestructura, medios, recursos de información, etc.); así como las ventajas y limitaciones de éste para poder relacionarlos con los objetivos, los contenidos, las estrategias y actividades de aprendizaje y la evaluación. Y es que una integración de medios como texto, gráficos, sonidos, animación y video, o los vínculos electrónicos, no tienen sentido sin las dimensiones pedagógicas que el diseñador del ambiente puede darles.

El desarrollo de los modelos AVA dependen en gran medida de la nube y de las tecnologías asociadas que permiten su funcionamiento (35), como consecuencia de ello y debido a la gran dependencia respecto a internet. Estas metodologías propician el acceso a la información en cualquier dispositivo y cuando se requiera, sin embargo presentan vulnerabilidades, tales como el incremento de las posibilidades de fuga de datos (36) y las asociadas a servicios web como inyección SQL, pérdida de autenticación y gestión de sesiones, configuración de seguridad incorrecta e inclusión de archivos remotos (37).

Sostenibilidad de la Educación y el COVID-19

El rápido crecimiento de innovación tecnológica ha propiciado una oportunidad para abordar las crecientes preocupaciones de la sociedad, como puede ser un sistema educativo sostenible o la educación para la sostenibilidad (38,39). La educación para la sostentabilidad se centra en brindar habilidades y capacidades a los ciudadanos, para alcanzar sociedades sostenibles a largo plazo (9). Este concepto creado hace treinta años, tuvó como objetivo proporcionar al futuro ciudadano el conocimiento necesario para ser agentes activos de la continuidad y el equilibrio de la sociedad (40). En este sentido, las TICs tienen un papel crucial en la educación desde una perspectiva sostenible, creando un sistema actualizable para llevar a cabo esta tarea tan relevante. La educación sostenible está en continua adaptación debido a los cambios sociales, políticos y culturales (41).

En el año 2002 en la Asamblea General de las Naciones Unidas se declaró el periodo de 2010 a 2020 como la década de la Educación para la sostenibilidad, cuyo fundamento era la creación de una sociedad más viable para la humanidad e integrar el desarrollo en el sistema educativo en todos sus niveles(42). En el Foro Mundial Sobre Educación de 2015, se firmó la Declaración de Incheon que representa el compromiso de la comunidad educativa en favor del objetivo numero 4 para alcanzar estedesarrollo en al año 2030; en este documentose concibe una educación inclusiva, equitativa y de calidad, con mayores oportunidades de acceso al aprendizaje para la toda la vida (43).

A finales del año 2019 el mundo fue sorprendido por el virus SARS COV-2 COVID-19 originada en china con características de alta transmisibilidad y contagio que derivo en la pandemia a nivel mundial, que ha impactado a la educación y diversos aspectos de la vida cotidiana (25) . El Covid-19 obligó a los diferentes países del mundo a pausar todo trabajo no esencial, incluida la educación. De acuerdo con el Informe de la Organización de Naciones Unidas para la Educación (UNESCO) a finales de Mayo 2020 más de 190 países, con el propósito de evitar la propagación del virus, optaron por la suspensión de las clases presenciales afectando a más de 1.200 millones de estudiantes en todo el mundo (CEPAL, 2020). La UNESCO informó de la pérdida de más de dos tercios de un año académico debido al cierre total y parcial de escuelas, colegios y universidades a nivel mundial en afectando a unos 23,4 millones de estudiantes de educación superior y a 1,4 millones de docentes en América Latina y el Caribe. En este sentido, la Covid-19 impuso confinamientos que obligaron a pasar de la enseñanza presencial a la online, también conocida como e-learning (44,45). Este cambio modificó el proceso de aprendizaje y la interacción entre docentes y alumnos a costa de la disposición y predisposición de docentes y alumnos, llegando incluso a generar problemas de bienestar (46,47). La incorporación de las TIC en las instituciones educativas para fortalecer diferentes modalidades, desde la e-learning hasta la presencial, se había ido produciendo poco a poco como un proceso de mejora continua (48).

El uso de internet y las TICs ofreció una oportunidad única gracias a la cantidad de recursos pedagógicos y herramientas disponibles online, permitiendo realizar un acercamiento de la universidad a los hogares (49) . En el caso de las Instituciones de Educación Superior alrededor del mundo (50), se vieron obligadas a crear estrategias que garantizaban la continuidad y calidad en su proceso de enseñanza; principalmente mediante la creación de un paradigma de aprendizaje basado únicamente en un modelo virtual a través de diferentes plataformas tecnológicas como Zoom, Cisco o Blackboard Collaborate (51,52). Estas modificaciones a lo largo del curso académico y, por supuesto, entre países o incluso regiones pueden haber delimitado el proceso de aprendizaje de los estudiantes (4). Además, el profesorado se ha visto obligado a transformar sus materiales didácticos a un formato online, a través de técnicas de enseñanza con poca o ninguna formación y con una mínima práctica previa (51,53). Sin embargo, como ocurre con cualquier estructura, las TICs tienen problemas de seguridad que permiten a personas externas ingresar los datos, manipularlos o usarlos contra los usuarios. Esta situación ocurrió con una versión inicial del programa Zoom, que resultó en la selección de otra herramienta, como fue Cisco, para el proceso de enseñanza (54). Otras limitaciones identificadas fueron la

disponibilidad de una conexión a internet inadecuada para la transmisión de materiales multimedia, la disponibilidad de dispositivos (computadoras, tablets) y programas necesarios para la viralización.

Algunos profesores tenían experiencia previa ya que crearon o implementaron nuevos paradigmas basados en las TICs y la educación, experimentando y determinando la efectividad [31,32]. Sin embargo, la mayoría de los profesores, académicos y las instituciones, estaban lejos de estar preparados para el cambio abrupto a un entorno virtual de enseñanza y aprendizaje (50,51,53) . Estas constantes modificaciones en el entorno de aprendizaje virtual en la educación superior han sido complejas, sin un paradigma estándar y con un entorno experimental que cambiaba a medida que pasaba el tiempo (52,55). Para integrar plenamente las TICs en el sistema educativo para la sostenibilidad (4), es necesario comprender mejor las dificultades actuales, los participantes y la disposición de los agentes activos, es decir, los docentes, y el papel del Covid-19, como factor externo que obligó a la integración de un nuevo modelo virtual (51,53).

Educación STEAM y herramientas digitales

Los cambios económicos, sociales y Tecnológicos de siglo XXI, demandan un modelo de educación que permita integrar diferentes disciplinas académicas (56), en la formación de profesionales con conocimientos científicos y tecnológicos, con la capacidad de tomar decisiones de forma crítica y reflexiva ante los problemas globales y participar activamente en las posibles soluciones (57).

El acrónimo de STEM se utiliza para referirse a Ciencia, Tecnología, Ingeniera y matemáticas, por sus siglas en inglés: (Science, Technology, Engineering and Masths) un conjunto de conocimientos, habilidades y prácticas en disciplinas científico-tecnológicas(58) a las que se han adherido disciplinas como el Arte (STEAM) que promueven la creatividad. Este término apareció por primera vez en los años noventa introducido por la Fundación Nacional para la Ciencia en Estados Unidos (NFS) (Santillán Aguirre et al., 2020) y tuvo su mayor impacto en el año 2005 con la publicación del informe “Europe Needs More Scientists: Report by the High Level Group on Increasing Human Resources for Science and Technology emitido por la Comisión Europea (59).

En el año 2019 la IESE Business School presenta un informe de su investigación que refleja la opinión de 53 empresas españolas enfocadas en las necesidades actuales y competencias profesionales relacionadas con los empleos del futuro (60), en donde se requieren más profesionales con conocimientos y dominio de las tecnologías que predominan la industria 4.0 como el big data, automatización, inteligencia artificial y Block chain. Junto con los avances tecnológicos, científicos y económicos, se requiere que los profesionales potencien actitudes laborales como la comunicación asertiva, liderazgo, trabajo en equipo, innovación y creatividad para buscar soluciones a problemas desde otras perspectivas, así como resiliencia y adaptabilidad para enfrentar situaciones complejas y cambiantes(61).

Para alcanzar estos objetivos, los sistemas educativos a nivel mundial han adoptado como parte de sus currículos la educación STEAM promoviéndola a lo largo de toda la escolarización (Simó et al., 2020), con el objetivo de dotar de competencias, conocimientos y habilidades científico-tecnológicas a los futuros ciudadanos de una sociedad capaz de enfrentar y ser partícipes de los problemas tecnológicos actuales, brindando soluciones innovadoras que aporten al desarrollo social y económico de un país, lo que se traduce en una mejora calidad de vida (56,62).

Por lo expuesto anteriormente, la educación STEAM posee el enfoque basado en el desarrollo de competencias científicas, tecnológicas e ingenieriles (63), que promueven el aprendizaje activo y centrado en el estudiante (64). Algunos autores enmarcan la importancia de las metodologías activas en la práctica de disciplinas STEAM, como el aprendizaje basado en proyectos , aprendizaje colaborativo, basado en problemas, aula invertida y gamificación (56).

La era digital o era de la información ha marcado una progresiva y acelerada generación de proyectos de innovación educativa y herramienta digitales que contribuyen a la educación STEAM. Como ejemplo de todos ellos, destaca el GO-Lab en el área de la ciencia, el Chem-innova en el área de química y el KIKS. El proyecto GO-Lab, financiado por la Unión Europea, tiene por objetivo el fomento de la investigación científica a través del uso de laboratorios vía web y aplicaciones virtuales (65). Chem-innova es un proyecto que permitió el acercamiento de la química a niveles de educación primaria, combinado con elementos de gamificación que motivan a los estudiantes para experimentar con materiales no asequibles que de otra forma no estarían a su alcance (66). Por último, el proyecto KIKS(Kids Inspire Kids for Steam) evidencia el desarrollo de competencias claves en las áreas de ciencias, matemáticas, tecnologia , ingeniería , alfabetización y competencias multilingües (67).

A pesar de lo anteriormente descrito, no existen abundancia de estudios o proyectos centrados en educatión STEM e integración mediante la gamificación a nivel de estudios superiores.

Aunando las estrategias STEM y las nuevas modalidades de aprendizaje, basadas en la gamificación y el uso de las TICS, se proponen nuevos modelos de aprendizaje sostenibles que favorecen la integración y el autoaprendizaje del alumno y una mayor implicación y satisfacción en el educador/profesor lo que repercute en una mejoría del estado anímico a largo plazo y por tanto en la mejora de la seguridad y a la Sostenibilidad del Sistema

1.1. Objetivos

En este trabajo de Tesis se propone desarrollar un modelo desde la concepción teórico-metodológica para la introducción de la gamificación y las TICs como estrategia pedagógica en la Educación Superior, que favorezcan el desarrollo de las competencias STEAM en los estudiantes de las carreras que oferta la Universidad ECOTEC, Ecuador y a las ofertadas en Ciencias Sanitarias e Ingeniería de la Universidad de Córdoba, España.

Los objetivos se han estructurado en:

O1. Realizar una revisión bibliometrica sobre el impacto de las TIC y la gamificación en el desarrollo sanitario de las Instituciones de Educación Superior (IES) y sus docentes como agentes activos, destacando aspectos positivos, negativos y su actual crecimiento en campos STEM.

O2. Determinar los factores que contribuyen a la inclusión y uso de las TICs en Instituciones de Educación Superior ante situaciones extraordinarias (antes y durante la pandemia COVID-19)

O3. Analizar la influencia de la tecnología y el Covid -19 en el bienestar mental de los docentes con alta experiencia en educación STEM en las Instituciones de Educación Superior

O4. Desarrollar un modelo que permita la integración de la gamificación y las TICs para el fortalecimiento de la educación STEM y contribuya a la Sostenibilidad del Sistema Universitario en las IEs de Ecuador y España.

1.2. Hipótesis

Cada uno de los objetivos mencionados, se relacionan con una o varias hipótesis. Específicamente las hipótesis H1.1, H1.2 se relacionan con el O1, donde se ha realizado una revisión bibliometrica de la producción científica relacionado con el impacto de las TICs, gamificación y bienestar emocional en Instituciones de Educación Superior, sus docentes y el crecimiento en campos STEM:

H1.1: La utilización de la gamificación como herramienta promotora de motivación en los estudiantes de las instituciones de Educación Superior.
H1.2: La gamificación como herramienta clave para el desarrollo de la salud en Instituciones de Educación Superior sostenibles.

Las hipótesis H2.1, H2.2 se encuentran relacionadas con el O2, y estas se abordan en el artículo titulado “The Higher Education Sustainability before and during the COVID-19 Pandemic: A Spanish and Ecuadorian Case” (cita)

H2.1: Existe una asociación entre el uso de las TICs, las habilidades, el obstáculo para la integración y el país.
H2.2: Existe una asociación entre la experiencia laboral y el uso de las TICs, las habilidades y la importancia otorgada a estas.

Las hipótesis H3.1, H3.2, H3.3 se encuentran relacionadas con el O3, y estas se abordan en el artículo titulado “The Influence of Technology on Mental Well-Being of STEM Teachers at University Level: COVID-19 as a Stressor” (cita):

H3.1: Las dificultades que perciben los docentes como la deficiencia de formación, recursos o el estrés provocado por el COVID-19 se asocian con el nivel de ansiedad y depresión.

H3.2: La relación entre el nivel de ansiedad y depresión y su impacto en los docentes STEM que poseen alto nivel de habilidades en TICs y comprensión de la ingenieríaa.

H3.3: La educación STEM y su influencia como factor protector en el bienestar del profesorado universitario.

La hipótesis H4, se encuentra relacionada con el O4, y esta abordada en el capitulo IV:

H4: El modelo de integración de la gamificación y las TICs, específicamente en educaciónn STEM, depende de los factores emocionales y antecedentes personales, como la formación previa y disponibilidad de recursos, de los docentes a nivel de Educaciónn Superior.

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2

PUBLICACIONES

NUEVAS TECNOLOGÍAS EN LA EDUCACIÓN SUPERIOR EN ÉPOCA DE PANDEMIA. ESTUDIO COMPARATIVO ENTRE ECUADOR Y ESPAÑA.

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La generación de recursos educativos abiertos, ambientes virtuales de aprendizaje (AVA) e innovación tecnológica, son algunas de las tendencias educativas marcadas por las Tecnologías de Información y Comunicación (TIC), que se planificaban fortalecer en las instituciones de Educación Superior, a través de mayor inversión en recursos tecnológicos y capacitación docente que contribuyera al desarrollo de sus competencias digitales. Sin embargo, la aparición de la pandemia COVID-19 impactó a la sociedad a nivel mundial, y en el ámbito educativo a todos los niveles. Las Instituciones de Educación Superior se vieron en la necesidad de crear estrategias que garantizarán la continuidad y calidad en su oferta educativa soportada por TIC. El objetivo del presente de trabajo de investigación fue realizar un estudio comparativo de los principales aspectos relacionados con la inclusión y utilización de las TIC en ambientes virtuales en instituciones de Educación Superior en países como Ecuador y España. El tipo de investigación es de tipo cuantitativo. Se utilizó el cuestionario como método de recolección de datos, donde se incluyeron preguntas cualitativas con un rango de respuesta de (0 = totalmente en desacuerdo a 5 = muy de acuerdo) para encuestar a 55 docentes. Posteriormente, los datos se analizaron utilizando las versiones de SPSS versión 22. Las variables se estudiaron utilizando frecuencias, la media, U de Mann-Whitney y la cuantitativa según la edad se estudió utilizando Kruskal-wallis. Se encontró que los aspectos más relevantes en el uso de las TIC fueron el apoyo en el proceso de enseñanza- aprendizaje (EA), a través de la búsqueda de información, creación de material didáctico y utilización de herramientas virtuales que fomentaban el aprendizaje colaborativo y basado en juegos. Por otra parte, la escasez de recursos de hardware y una óptima conexión a internet fueron las principales limitaciones encontradas.

Palabras clave: TIC, COVID-19, Educación Superior, Ecuador, España

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NEW TECHNOLOGIES AND SOCIAL NETWORKS IN HIGHER EDUCATION. COMPARATIVE STUDY BETWEEN ECUADOR AND SPAIN

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Information and Communication Technologies (ICTs) and social networks have generated an impact on society in recent years especially in the educational field, transforming both informal and formal contexts. In informal contexts, the technologies are defined by the imminence and availability of most of the information, allowing the development of digital search, creation and literacy skills. In formal contexts, these have transformed the teaching-learning processes (TL), letting the insertion of new methodologies in the classroom, in addition to the use of tools for creating interactive and attractive content for students. In addition, these tools have facilitated the communication among students and teachers. The objective of this paper was to carry out a comparative study of the aspects that teachers' value most in the inclusion and use of ICTs and social networks in the classroom in higher education institutions in Ecuador and Spain. This was done using the comparative method in the descriptive and interpretative phases, using a questionnaire as a data collection tool.The questionnaire used was base on qualitative questions with a range of answer from (0=strongly disagree to 6=strongly agreed). Posterior the data was analysis using the SPSS version 22, in which the qualitative variables were studied using frequencies, mean, U de MannWhitney and the quantitative as age were studied using Kruskal-Wallis.

It was found that one of the aspects most valued by teachers is the incorporation of active methodologies in the TL process, and the motivation it awakens in students. One of the main constraints in Ecuador is the lack of teacher training in ICT, which is a challenge to its performance as opposed to Spain, where the implementation of these new methodologies is well established.

keywords: icts, social networks, higher education, active methodologies, ecuador, spain.

Article

Gamification as a Promoting Tool of Motivation for Creating Sustainable Higher Education Institutions

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Abstract: Higher Educational Institutions (HEIs) are responsible for creating healthy and sustainable environments for students and teachers through diverse educational paradigms such as gamification. In this sense, the Healthy People 2030 and the Sustainable Development Goals indicated the imperative to provide inclusive and equitable quality education to promote a healthy environment and life. The principal objective was to analyse the impact of gamification on health development in HEIs, highlighting their positive and negative effects. To achieve such an objective, a bibliometric analysis was carried out. The 257 documents showed no significant increasing trend in the last decade ($p > 0.05$) related to the pandemic. Most of the publications were conferences (45%), and the few published articles were the documents with more citations ($p < 0.001$). According to their index in Journal Citation Reports, there were significant differences between the citations of articles published in journals ($p < 0.001$). The analysis of journal co-citations showed that the leading journals (such as Computers in Human Behavior) had a significant part in the clusters formed ($p < 0.001$), conditioning also the keywords, especially the term "motivation". These findings were discussed, concluding that the experimental studies focused on the teachers' adverse effects are yet to come.

Keywords: health and sustainable environments; gamification; higher education institutions; motivation

1. Introduction

Higher Educational Institutions (HEIs) are responsible for creating healthy environments for students and teachers [1]. This function, framed by the Health Promoting University's definition, focused on encouraging health in HEIs, considering the relevance of sustainability, from the quality of education to adequate mobility [2]. This approach creates sustainable organisational modifications that generate circumstances supportive of health and well-being in line with an ecological view of health [3]. This understanding of sustainability connected to the concept of a Health Promoting University is characterised by education and research features supporting innovation reinforced by proper evaluation [4]. Such an approach has been emphasised since the late 1990s in different healthcare colleges and centres across countries [3], highlighting students' academic and personal development and a healthy, supportive workplace for teachers [5].

Additionally, HEIs are dynamic agents of change for sustainable development; teaching informal contexts contributes to the training of professionals in the 21st century [6]. The use of project-based pedagogies for sustainability allows them to develop critical, reflective, creative, and resilient thinking skills as well as attain greater mastery of ICT to engage and respond socially to the needs of their interconnected environment [7]. For students, academic success and personal growth are critical factors in the self-esteem and self-perception of students [8,9], confirming their worthiness and emotional and mental health for the rest of their lives [10,11]. Academic achievement is co-dependent on health problems that positively or negatively impact younger people's or children's well-being [12]. One example of this association is physical activity, whose higher frequency increases academic performance [12].

Meanwhile, this academic performance is also linked to the educational quality, which needs to adapt to students' needs and requirements of the HEIs, being framed in the Sustainable Development Goals [13,14]. Such quality depends on the technological tools and adequacy of the workplace for the teachers' skills, training, and knowledge [15,16]. Additionally, these tools, also known as information and communication technologies (ICTs), can cause teachers stress, technostress, and anxiety, among other emotional or mental distress problems [6,17]. Despite these side effects, HEIs have integrated the utilisation of ICTs since they are used on a daily basis by students and result in greater connection or feedback between students and teachers, incorporating better knowledge and improving the students' academic performance [7,18]. The negative or positive impact of these tools on the health of the different agents (students and teachers) in HEIs and their healthy environments depends on diverse factors from the type of educational paradigms, such as gamification or serious games, the implementation of sustainable education, the safety and occupational

health measures for the teachers, the integration of the new strategies for creating healthy environments, or change in the design of education from face-to-face to online teaching [6,19–21].

2. Social and Sustainable Development, Gamification, and Health

Numerous studies, as well as organisations [22–24], have indicated the need to provide a high quality of education, being even framed in the Sustainable Development Goals (SDGs) [22] and defined as the 4th goal in the Sustainable Agenda 2030 [23]. In this sense, different goals from the Healthy People 2030 [24] and the SDGs [25] indicate an imperative to provide inclusive and equitable quality education to promote a healthy environment and life. Moreover, the U.S. Department of Health and Human Services indicated that education could prevent diverse illnesses, such as obesity or hepatitis, the pinnacle of the prevention of the 4th grade [26]. Based on all the data, education is critical for cultivating sustainable, healthier social environments [23,24,27,28]. The role of education in creating such environments seems to be based on its capacity to transform people's lives by integrating values, knowledge, skills, and a global vision towards social welfare [27]. Therefore, it is imperative to include critical thinking, systematic reflection, collaborative working, and students' responsibility from a practical, multidisciplinary, and comprehensive approach [29].

Several authors have indicated how integrating ICTs in education promotes healthy development [30,31], including the self-perception [9,32]. In this context, new active methodologies and pedagogical strategies focused on ICTs, mainly serious games in science, technology, engineering, and mathematics (STEM), improve the motivation and self-esteem of students [33–35]. In HEIs, the use and implementation of games, also known as gamification, has aimed to motivate and create interest in students [36,37] through training experiences [20]. The teaching approach has increased in the last decade based on the ease and little programming required, and previous training and knowledge [20,38,39], despite being theorised and hypothesised since the 1990s. One reason for the popularity of gamification in higher education seems to be the improvement of motivation, flow, skills, and learning perceived by both the teachers and students [36].

Another reason could be explained by online teaching, known as e-learning, or a combination of face-to-face with online education, known as b-learning, based on using ICTs and games as basis instruments for the teaching process [40,41]. Incorporating ICTs in educational institutions to strengthen different modalities, from e-leaning to face-to-face, has taken place little by little as a continuous improvement process [42]. However, with the appearance of COVID-19, educational institutions were forced to

generate pedagogical and technological strategies that would allow them to give continuity to current programs. Educational institutions needed to abruptly migrate to e-learning, including the ICTs, without understanding the positive (such as motivation) or negative (such as level of stress and anxiety) effect [43]. As a result of the COVID-19 pandemic and how most studies focused on elementary and middle schools [42], the role and impact of gamification in HEIs during the last two decades seems to be undervalued. Therefore, the objective of this research was to analyse the current scientific knowledge regarding the impact of ICTs, specifically gamification, on health development in HEIs in the last two decades, highlighting the positive and negative effects. In addition, a secondary objective was to determine the impact of ICTs and gamification on teachers as active agents in HEIs and their current growth in STEM fields, especially in medical areas.

3. Materials and Methods

3.1. Design of the Study

The inclusion, use, and implementation of ICTs have positively impacted the teaching– learning process and allowed the incorporation of new methodologies such as gamification and game-based learning, increasing the motivation and interest of students using tools, applications, and virtual laboratories, the latter widely used in STEAM disciplines [20].

Based on the previous description, bibliometric studies have become an effective tool for determining the quality of current scientific knowledge and its impact on the field of education [44–46]. Bibliometric studies contextualise scientific information at a national and international level, contributing to understanding the relationship between information and communication technologies and the education field [47,48]. As pointed out by Harman et al. [44], citations and analysis of previous works are an essential contribution in any field, especially in education. Harman et al. [44] and Trinidad et al. [45] analysed the impact of gamification in the education field from different time periods (from 2010 to 2013 and 2011 to 2019). Both time frames focused on the inclusion and initial use of gamification in education [49], although the ICTs in education have been included since the early 2000s [43]. Moreover, these studies [44,45] focused only on gamification, and other possible ICTs were excluded in the educational field without distinctions. The current research was designed to provide further insight into two aspects: the cover of an underrated topic, based on ICTs, especially the gamification, in STEM education, including the health field, and a combination of qualitative and quantitative analysis. To achieve both insights, a deeper research based on a bibliometric design focused on ICTS, emphasising gamification in the STEM field, including health education, based on the last two decades and with

specific research questions, was carried out. The research questions (RQs) and workflow were set according to Zupic and Cater [50]:

RQ1: Which is the publication trend for ICTs, especially gamification, in STEM education?

RQ2: Which countries and journals contribute to this field, and what is their relationship?

RQ3: Which are the top publications and their impute on ICTs and gamification in STEM education?

RQ4: How has the knowledge in this field grown over the last two decades?

RQ5: How have the research focus and major topics evolved in the timeframe?

RQ6: What influence do ICTs and gamification have in health education as a subsection of STEM education?

The procedure of this research followed the recommendations of previous researchers [51] following the five-step research design (with the design questions and selection of bibliometric and visualisation methods), compilation of the bibliometric data (select the databases and execute the searches with the filters), analysis (bibliometric methods and use of supportive tools), visualisation, and interpretation.

3.2. Selection of the Databases and Design of the Research: Exclusion and Inclusion Criteria

The information search was carried out in the Web of Science (WOS) and Scopus databases to obtain further information and reduce the possible bias of selecting documents [52]. The bibliographic search was carried out without using the terms Medical Subject Heading (MeSH), since the keywords identified according to the objectives of the present investigation were not determined according to their definition (Table 1). The reason was based on game theory which is a discipline that impacted the 1950s and 1960s, was created by Nash in 1925, and achieved consolidation in different areas of knowledge (mainly administrative ones) and resolved real-world problems [53]. Additionally, the term "gamification" has been modified in the last decade, and newly derived methodologies applied to education in 2010 [49] and game-based learning in 2017 and linked to ICTs have generated a change in the educational paradigm, which are terms that due to their current relevance were considered in the bibliographic search. Additionally, "ICT" terms were used to identify the tool, and "gamification" was implemented for the educational paradigm, resulting in data based on games as educational tools for healthy environments. The Boolean operators used were "OR" and "AND" to link the terms and identify the "title", "abstract", and

"research" framed in the research questions.

Table 1. MeSH terms and description.

MeSH terms	Description
Universities	Educational institutions providing facilities for teaching and research and authorised to grant academic degrees.
Learning	Relatively permanent change in behavior that is the result of past experience or practice. The concept includes the acquisition of knowledge.
Education	Used for education, training programs, and courses in various fields and disciplines, and for training groups of persons.
Models, Educational	Theoretical models which propose methods of learning or teaching as a basis or adjunct to changes in attitude or behaviour. These educational interventions are usually applied in the fields of health and patient education but are not restricted to patient care.
Educational Technology	Systematic identification, development, organisation, or utilisation of educational resources and the management of these processes. It is occasionally used in a more limited sense to describe equipment-oriented techniques or audiovisual aids in educational settings.
Technology	The application of scientific knowledge to practical purposes in any field. It includes methods, techniques, and instrumentation.
Game Theory	Theoretical construct used in applied mathematics to analyse certain situations in which there is an interplay between parties with similar, opposed, or mixed interests. In a typical **game**, decision-making "players," whom each have their own goals, try to gain an advantage over the other parties by anticipating each other's decisions; the **game** is finally resolved due to the players' decisions.
Games, Experimental	Games designed to provide information on hypotheses, policies, procedures, or strategies.

The exclusion criteria used included the following. First, the period to produce the documents being selected covered only the last twenty years, since the ICTs have been included in education in the last two decades [42], and gamification has changed in the last decade as well [49] being framed in the Decade of Education for Sustainable Development (DESD) [54]. In addition, articles focused on the elementary and middle educational institution; focused on students' perspectives or health problems not related to the educational paradigm or ICTs in their education; studies based on general education with the perspective of patients or other end-users; and finally studies that lacked analysis of ICTs' role were excluded as well. Additionally, the document type was

determined to exclude non-scientific productions, such as projects. The data were analysed and selected or eliminated according to the year of publication, journal, keywords, title, and abstract based on the exclusion criteria.

3.3. Research Strategies: Exploratory and Final Research

In December 2020, the exploration of related terms began where different combinations included new technologies, ICT or TIC gamification, serious games focused on Higher Education; however, being global terms, the results obtained did not fit the required approach. The primary search strategy in each database was implemented according to the keywords selected in January 2021. The initial search was carried out only in WOS with the following terms TI = ("TIC") OR TI = ("ICT") OR AB = (TIC) OR TI = (ICT) OR AK = (TIC) OR TI = (ICT) AND TI = (GAMIFICATION) OR TI = (LUDIFICATION) OR TI = (SERIOUS GAME) OR TI = (GAME-BASED LEARNING) OR AB = (GAMIFICATION) OR AB = (LUDIFICATION) OR AB = (SERIOUS GAME) OR AB = (GAME-BASED LEARNING) OR AK = (GAMIFICATION) OR AK = (LUDIFICATION) OR AK = (SERIOUS GAME) OR AK = (GAME-BASED LEARNING) AND TI = (HIGHER EDUCATION) OR TI = (UNIVERSITY) OR AB = (HIGHER EDUCATION) OR AB = (UNIVERSITY) OR AK = (HIGHER EDUCATION) OR AK = (UNIVERSITY). As a result, 94,908 documents were obtained and downloaded in various csv document formats for later analysis.

The results obtained in the exploratory research strategy were linked to the term ICT and its term in Spanish. The great number of results and its heterogeneity indicated that the initial search was too wide for an adequate analysis. It was observed that the term TIC is a term that has different connotations because it is used to abbreviate meanings related to different categories of the database [18]. An example of this issue was that the term TIC also included the Materials Science Multidisciplinary, Metallurgy Metallurgical Engineering and Chemistry Physical reference TiC powders (titanium carbide powder). Their different combinations, Engineering Electrical Electronic, is related to the investigation of materials fused with cobalt (Co-TiC), and materials for electrical conductivity (titanium carbide (TiC)) in Psychiatry and Clinical Neurology are commonly related to research on Tourette Syndrome and Tics disorders in children and adolescents. Based on the results, in June 2021, a new search was carried out, considering the exclusion of the ICT abbreviation used for

Information and Communication Technologies in Spanish (ALL = ((ICT) AND (GAMIFICATION OR SERIOUS GAME OR GAME-BASED LEARNING) AND (HIGHER EDUCATION OR UNIVERSITY)). In this month, the research was implemented in the Scopus database (TITLE-ABS-KEY (ICT) AND TITLE-ABS-KEY (GAMIFICATION OR SERIOUS-GAME OR GAME-BASED-LEARNING) AND TITLE-ABS-KEY (HIGHER-EDUCATION OR UNIVERSITY)). As a result, 152 documents were obtained in Scopus and 845 documents were obtained in WOS, which were exported in Excel and bibliographic formats (csv and enw), including fields such as author(s), type of publication, title, abstract, keywords, year of publication, language, number of citations, unique identifier, and funding agencies. In the search, 997 documents were identified and subsequently analysed from their title, abstract, and keywords. During the analysis, 540 documents were eliminated, since they focused on aspects unrelated to the object of the current research, such as the perception of teachers or levels of satisfaction related to students. In addition, 156 documents were identified as linked to research focused on initial, primary, and secondary education levels, which were excluded. Other 44 duplicate documents were removed using Endnote. Finally, 257 documents were included related to the use of ICTs in HEIs, which is linked to studies that include gamification or game-based learning (Figure 1).

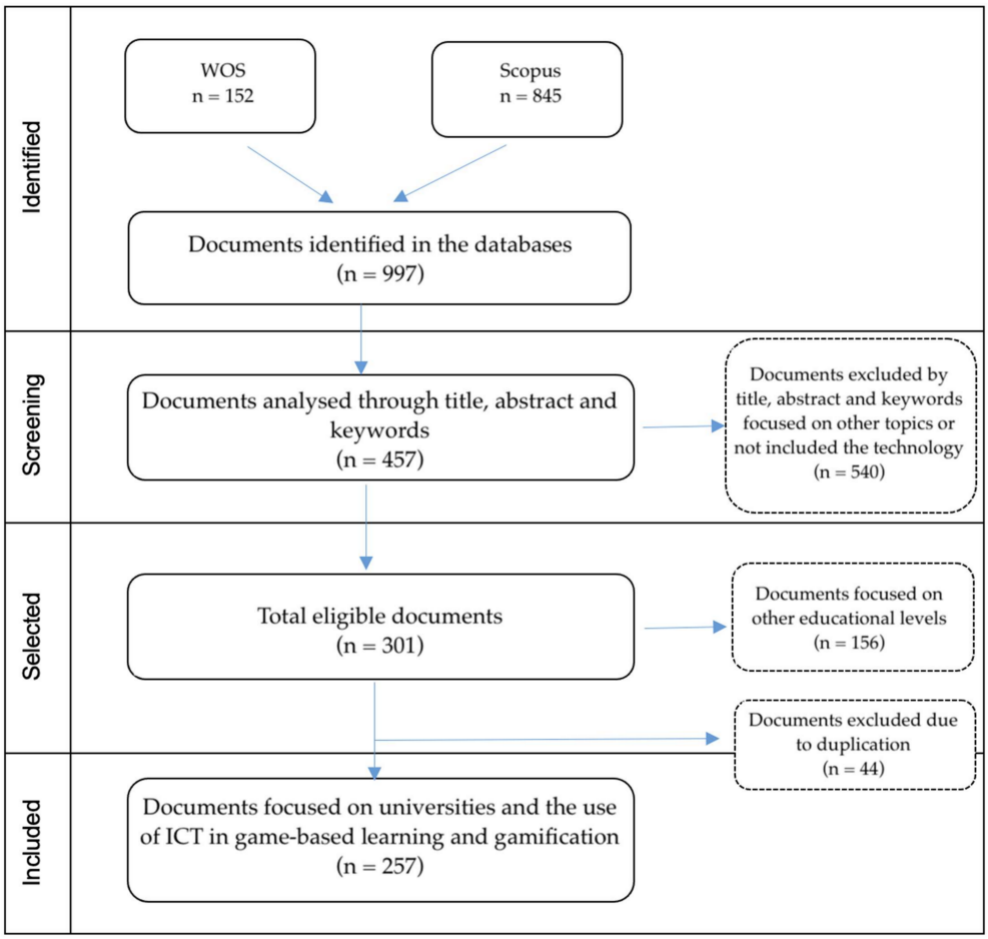

Figure 1. Flow diagram of the selection of articles for the quantitative analysis.

3.4. Analysis: Supportive Tools

The results from the research were analysed initially using descriptive analysis, such as the frequencies of documents per country and year, the language, primary sources, the field of the publication, the leading scientific institutions, associations among nations, the primary authors in the area, and the index keywords used. After obtaining all the data, SPSS program version 28 (IBM Corporation, Armonk, NY, USA), VOSViewer version 1.6.15 (Ness Jan van Eck, Leiden, the Netherlands), Excel version 17 (Microsoft Corporation, Redmond, WA, USA), and Endnote (Clarivate Analytics, London, UK) were used to analyse the information. The selection of these programs was based on the research questions being required, including descriptive analysis (Excel and SPSS), citation analysis (SPSS and VOSviewer), cross-reference (Endnote),

bibliometric mapping (VOSViewer), and networking analysis (VOSViewer and SPSS). Meanwhile, the Bibliometrix program (Massimo Aria, University of Naples Federico II, Naples, Italy), which is an R statistical program for quantitative analysis in the scientometrics and bibliometric area, was not included, since the SPSS could provide further quantitative analysis [51,55,56].

The Excel program was used to identify and visualise the data, such as the frequency of publications per year or the number of documents each country produced. Endnote was used to eliminate the duplicated records and identify possible cross-references such as the studies from previous research fields [47,48], which was also included in the research of Trinidad et al. [45] and found in the final sample. The VOSviewer program used the csv format to identify and create mappings of co-citation, co-occurrence, and clustering between the authors, countries, and keywords, utilising a multidimensional analysis method. The SPSS program was selected for the citation analysis and the connection between countries, the evolution of the publications, and the relevance of quantitative indicators in this topic.

The statistical analysis of the data was structured according to the quantitative or qualitative variables. The variables were structured according to the number of publications per country, institution and author, and citations. In addition, quantitative metrics (Journal Citation Report, quartile, and Journal Citation Indicator) were used to analyse the possible impact of published work and journal relevance. The descriptive analysis focused on relative frequencies, mean, and standard deviation (SD). For quantitative analysis of the 257 documents, the Mann–Whitney and Kruskal–Wallis tests and the Spearman's correlation were used, based on the results obtained in the Kolmogorov–Smirnov test ($p < 0.001$). The Chi-square test for a sample indicated significant differences between countries to produce documents; additionally, the Cramer's V test was used to determine the effect size for country and publications according to the years.

4. Results

4.1. General Results

4.1.1. Publication Type, Language, and Trend (RQ1)

The results of the 257 documents showed that 35.9% of the available documents were articles, 45% were conference articles, and

18.7% were conference reviews. In recent years, there has been a growing trend of academic congresses where researchers present their scientific disclosures (with a maximum of pages). This response to the higher percentage of documents found that the mean of citations was lower (4.2; SD = 12.7) than those of other studies in different fields, which could be linked to the frequency of published papers. Moreover, the analysis of the citations per country ($p = 0.12$) and year of publication ($p = 0.053$) indicated no significant differences. This lack of significance could be associated with the dispersion of the data, being 93 documents from Spanish institutions and 164 from other institutions around the world.

These results matched a recent bibliometric analysis focused on gamification, which identified that 63% were conferences papers [45]. The central organisation and producer of the conference was the International Academy of Technology, Education and Development (IATED) (22.6% of the total documents) and the IEEE as the second organisation (6.2% of all the papers). Both results were fascinating, since IATED was created for any field focused on educational approach, indexed in Conference Proceedings Citation Index (Web of Science), and whose origin is based on the Polythetic University of Valencia [57]. Meanwhile, the Institute of Electrical and Electronics Engineers (IEEE) is a significant organisation with indexed journals, such as IEEE Transaction on Education, which strongly relates STEM education with interdisciplinary application [58]. Therefore, the conference papers seem to be associated with relevant editorial organisations. Regarding the language used in the research, English predominates in different international journals (92.4%), followed by publications in Spanish (6.8%), Russian, and Hungarian (0.4%), respectively.

Figure 2 shows the frequency of academic publications related to ICTs, gamification, and STEM in higher education. There is a growing trend from 2013 to 2018, with 2018 and 2019 featuring more effective scientific communication from journals. Additionally, the median of the year of publication was set in 2018, which matched with the more substantial number of publications. In 2020, there was a decrease in the number of publications; this may be related to the still existing COVID-19 pandemic [59,60], which led to a change in focus from looking at gamification trends and their impact on STEM competencies due to experiences and good practices that will allow their contribution to the virtual modality.

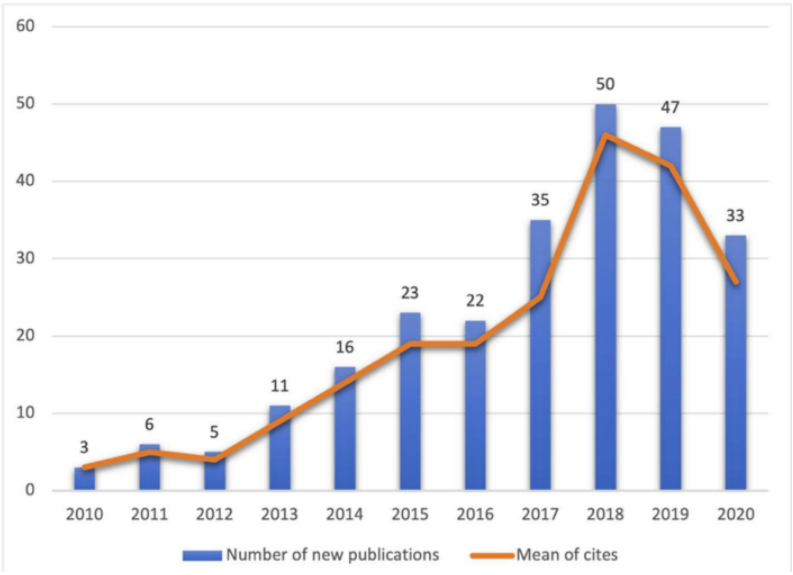

Figure 2. The number of documents per year and mean citations per year.

These results showed how this specific research area continues to develop, since more publications are conference papers. The publication trend is experimenting with a light decrease, which could be explained by the decline in the publication in a specific area such as Engineering or the shift to experimental analysis. These results match those of Dégila et al. [61], which identified a decrease in e-learning in education publications and indicated how this decrease could be partially motivated by the COVID-19 pandemic. Nonetheless, the precious bibliometric analysis has not fully presented a possible reason for this research area's decline.

4.1.2. Publications and Collaborations between Countries (RQ2, RQ3, and RQ4)

The top five countries with more documents (Table 2) had significant differences ($p < 0.01$) regarding the number citations and documents, among which Spain was the leader (mean = 5.62; SD = 18.38; CI 95% = 9.39–1.83), followed by Italy (mean = 2.86; SD = 5.8), the United Kingdom (UK) (mean = 11.17; SD = 18.04), Croatia (mean = 0.5; SD = 0.71) and the United States (US) (mean = 3.2; SD = 7.47). The number of citations of the top five countries was 456 citations for Spain (46.0%), 40 citations for Italy (4.0%); 134 citations for the UK (13.5%), 5 citations for Croatia (0.5%), and 32 citations for the US (3.2%). In this sense, no significant differences were found between the citations per document and countries ($p = 0.186$).

Table 2. Count of papers per country from the data.

	Country	Count of, Documents	Frequency		Country	Count of Documents	Frequency
1	Spain	93	36.20%	23	Belgium	2	0.80%
2	Italy	14	5.40%	24	Brazil	2	0.80%
3	UK	12	4.70%	25	Estonia	2	0.80%
4	Croatia	10	3.90%	26	India	2	0.80%
5	US	10	3.90%	27	Namibia	2	0.80%
6	Germany	9	3.50%	28	Philippines	2	0.80%
7	Norway	9	3.50%	29	Romania	2	0.80%
8	Indonesia	5	1.90%	30	Russia	2	0.80%
9	Japan	5	1.90%	31	South Africa	2	0.80%
10	Portugal	5	1.90%	32	Sri Lanka	2	0.80%
11	Hungary	4	1.60%	33	Sweden	2	0.80%
12	Ireland	4	1.60%	34	Taiwan	2	0.80%
13	Slovenia	4	1.60%	35	Turkey	2	0.80%
14	Bulgaria	3	1.20%	36	France	2	0.80%
15	Chile	3	1.20%	37	Argentina	1	0.40%
16	Colombia	3	1.20%	38	Canada	1	0.40%
17	Ecuador	3	1.20%	39	Costa Rica	1	0.40%
18	Finland	3	1.20%	40	Cuba	1	0.40%
19	Greece	3	1.20%	41	Czech Republic	1	0.40%
20	Peru	3	1.20%	42	Denmark	1	0.40%
21	Slovakia	3	1.20%	43	Others	13	5.20%
22	Australia	2	0.80%				

Despite there being no significant difference for the citations, the country was linked to the Journal Impact Factor of the year of publication ($p = 0.046$) and 2022 ($p = 0.012$) as well as the percentile ($p < 0.05$). The number of citations per document was linked to being indexed in the Journal Citation Report (JCR) as an Emerging source or Social or Science Citation Index ($p < 0.001$). The data indicated that 12.8% were indexed, and 16.0% were included as Emerging sources, showcasing the difference between being indexed ($p < 0.001$) and not being indexed in the database ($p = 0.04$). These results manifest as previous research indicated that the JCR is a crucial point used by the authors to present their results and analysis.

Additionally, these findings are in sync with previous bibliometric articles in the educational field that indicated a high presence of European countries, especially Spain [45,61]. The initial relevance of European countries could be linked to the UNESCO initiatives from the Decade of Education for Sustainable Development and the fourth goal of sustainable development goals of the agenda 2030, which was related to leading [23,54].

Such results are also reflected by the top ten articles identified in this topic (Table 3), which are sorted by the number of citations. The ten articles with the highest citations were analysed according to the number of citations and the type of studies (Table 3). Based on the number of citations, among the ten most cited articles (Table 3), there are three observational studies, two theoretical studies or reviews, and five experimental studies based on a qualitative design. The results indicate that pre-and post-experiments based on qualitative design are the most common in this area.

Table 3. The top ten most cited documents.

	Title	Year	Journal	Quartile and JCR Year of Publication	Thematic Area	Study	Country	Citations All Databases
1	Serious games and learning effectiveness: The case of It's a Deal!	2012	Computers & Education	Q1 (2.775)	Computer Science, Interdisciplinary Applications	Article	Spain	146
2	Exploring the computational thinking effects in pre-university education	2018	Computers in Human Behavior	Q1 (4.306)	Psychology, Multidisciplinary	Article	Spain	76
3	Gamifying an ICT course: Influences on engagement and academic performance	2017	Computers in Human Behavior	Q1 (3.536)	Psychology, Multidisciplinary	Article	Spain; Portugal	76
4	An application of adaptive games-based learning based on learning style to teach SQL	2015	Computers & Education	Q1 (2.881)	Computer Science, Interdisciplinary	Article	Turkey	57
5	Gamification: a systematic review of design frameworks	2017	Journal of Computing in Higher Education	Q2 (1.517)	Education & Educational Research	Article	United Kingdom	56
6	Serious games and the development of an entrepreneurial mindset in higher education engineering students	2014	Entertainment Computing	-	Computer Science, Interdisciplinary Applications	Review	Spain	56
7	Training disaster communication by means of serious games in virtual environments	2011	Entertainment Computing	-	Medicine General and Internal	Article	Italy; Spain	45
8	Motivation, students' needs and learning outcomes: a hybrid game-based app for enhanced language learning	2016	SpringerPlus	Q2 (0.982)	Multidisciplinary Sciences	Article	Germany	34
9	Learning style analysis in adaptive GBL application to teach SQL	2015	Computers & Education	Q1 (2.881)	Computer Science, Interdisciplinary	Article	Spain	28
10	Using Mobile Health Gamification to Facilitate Cognitive Behavioral Therapy Skills Practice in Child Anxiety Treatment: Open Clinical Trial	2018	JMIR SERIOUS GAMES	Q1 (3.351)	Medical Informatics	Article	United Kingdom	27

Table 3 shows how the most relevant investigations (9/10) articles were published in Europe: five in Spain, two in the United Kingdom, one in Italy, and one in Germany; only one article was published in Turkey. In addition, it is reflected that the most cited articles are related to the applicability of game elements in the classroom. They were focused on understanding the essential elements to include in the design of the gamified components [62,63], academic performance [64], identifying their impact on learning process [65–68], motivation [69], and its effect on the development of skills [66,68,70], which are mainly linked to STEM education in the main text near the first time they are cited.

The table showed how eight publications were indexed in JCR and placed in the first or second quartile (Q1 and Q2). These results matched with the results from the Kruskal– Wallis test, being the tests statistic set at 51.86 and $p < 0.001$. The pairwise comparison and the adjusted p-values highly indicated a significant difference between not being indexed, being Q1 or Q2 ($p < 0.001$), and being Q1 and Q4 ($p = 0.019$). Moreover, the correlations indicated that a high quartile, such as Q1 or Q2, was associated with more citations ($\rho = 0.427$; $p < 0.001$). Another aspect that was linked to the citations and quartile was the Journal Citation Indicator (JCI) of 2020 that showed being over the mean of citations ($p < 0.001$). Additionally, the JCI was associated with the country; more differences between the significant country (Spain) compared to others were present ($p < 0.001$).

In addition, the data (Table 3) indicated that the most relevant articles were published in the 2010s; their thematic area were focused on Education, Multidisciplinary, or Health. These results were in sync with being indexed in the JCR and the year of publication, indicating that currently, in this area, there was no significant difference for the year of publication and being indexed ($p = 0.053$). Table 3 also indicated how most documents were published in Spain, focusing on the impact of gamification or other ICTs as motivational tools.

The top five articles regarding citations (Table 3) were carried out in Spain, Portugal, Turkey, and Scotland. These research studies were published from 2012 to 2018, matching the modification of the definition of gamification in 2010 and its posterior effect analysis in the HEIs [49]. Moreover, the top five articles were published in highly important journals, in the first and the second quartile, linked to the computing field.

The most cited article with 174 citations is from Spain, which shows

that factors influence learning effectiveness through serious games [62]. This article focused on developing and evaluating a serious game set in the University of Alicante for English courses. The research was conducted using English Studies students, implementing a pre-and postquestionnaire with a quasi-experimental design. The article recognises the relevance of serious games in education. It highlights the importance of using immersive and interactive environments to help develop and improve skills, in this case, intercultural communicative competence, mainly achieving an adequate language level (middle-high level of English). This study indicated the effectiveness of gamification as an essential tool for future teachers or students. In addition, the article provides further factors, such as the observational impute of the end-users, that contribute to the inclusion of serious games in the learning process. The report states that games elements must include the learning results to be achieved and must be designed to promote student involvement.

The second article was a narrative review of the effects of computational thinking in pre-university education [63]. This article highlights the importance of computational thinking as an essential component in developing a reflective and critical education to solve everyday ICT problems. This paper presented the idea of ICTs, including gamification, as tools for computational thinking in STEM educational programs. However, this article indicates that such an approach has been studied and analysed in elementary, secondary, and post-secondary institutions, with no interest in university educational centres. This research highlights the lack of articles for less relevance of these methodologies in HEIs compared to other educational levels [71].

The third article is also a pre-and post-test experimental design, which was carried out for one group [64]. The methodology included a questionnaire and experimental interview based on undergraduates enrolled at an ICT course and focused on demonstrating the effectiveness of game-based learning considering the adaptability to the students' learning [64]. This mixed approach aimed to determine the impact of gamification on university students' performance and its effectiveness in their learning process. The results highlighted in this Turkish research showed a positive effect of gamification in the students' motivation and engagement in their learning process. This article includes a highly relevant aspect of maintaining the students' motivation and performance obtained via gamification. The researchers indicate that to achieve the previous

goals via gamification, the role of the instructor should retransfer to the students. This shift positively affected the students' engagement, but for a few, it negatively affected their performance.

The fourth article focused on a pre-and post-experiment design, based on 120 university students with no knowledge of SQL (Structured Query Language) [68]. The study included mainly Scottish undergraduate students from diverse HEIs (such as the University of the West of Scotland). The participants were divided into no-computing and computing students to determine the impact of gamifying to learn SQL as a coding language. The results of this Scottish experimental study pointed out that the students with the gamifying experience had better learning outcomes, such as performance and time to finish tasks.

The final research [65] was a systemic review that analyses the most researched gamification frameworks in the educational field. This systematic review identified 40 articles whose objective was to determine the impact of gamification in education. This research identified three prominent types of users: educators, designers, and researchers. This review indicated the importance of considering the main characteristics of the game elements and the focus and applicability in the higher education [65].

Additional to the results per country and top ten publications, the country co-authorship identified four clusters,190 documents with connections between ten countries and 26 links, indicating a low level of co-authorship. Despite this, the bibliographic coupling (Figure 3) identified more links (93 links) in 13 countries. The first cluster in pink was formed by five countries and 40 links (42.6%), which was led by the United States (US) with nine links and eleven documents. The countries from this cluster were present in 35 papers. The 2nd in green was formed by three countries, 23 links (24.5%), and 39 documents (18.5%), which was led by Italy with ten links and 21 papers. Three countries also formed the third cluster, which had 17 links and was presented in 113 documents, which was led by Spain (12 links and 98 papers). The last cluster was formed by two countries, with 14 links and 24 documents, led by the UK with ten links and 12 documents. Moreover, the highest organisation with more publications was the Polytechnic University in Valencia, with 59 documents representing 22.96%. According to the international ranking, these results could be explained by the fact that this University has a high impact in the engineering and interdisciplinary field [72].

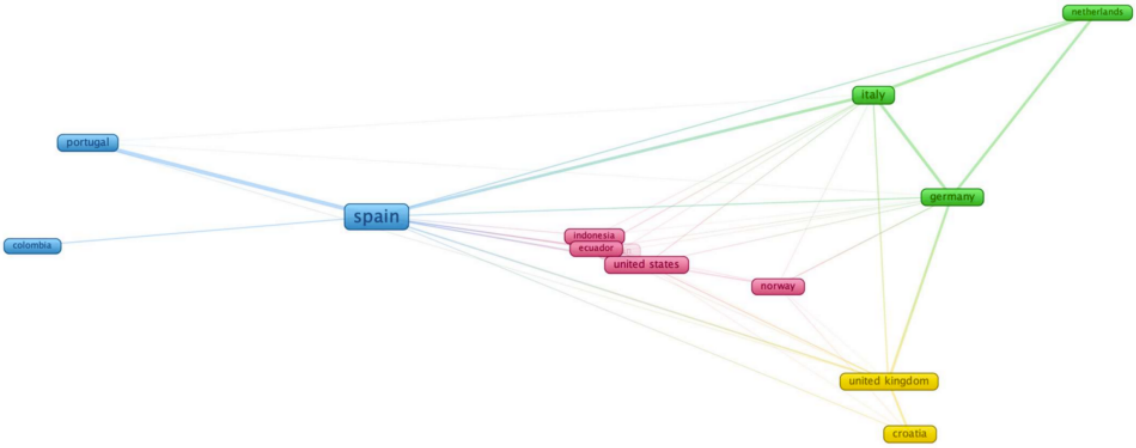

Figure 3. Collaboration among countries.

These findings highlighted the new educational methodologies integrated into different European countries, with a high visualisation of Spanish researchers and HEIs. Most articles focused on reviewing or carrying out initial experiment designs, being the last published during the previous five years. Furthermore, the connective networking established how the countries with more publications were linked through the co-reference to other less representative countries, such as Spain with other European or South American countries [73–75]. Although the networking was small compared to other bibliometric studies [46], the networking showed how countries determined the influence of gamification and other ICTs in STEM education in HEIs [71,76]. Despite the links between countries, many studies indicated how gamification in HEIs was rarely compared to elementary or secondary educational institutions [63]; further research is needed on HEIs regarding the impact of gamification [73–75].

4.1.3. Journals More Relevant in the Topic (RQ4)

The frequency of articles published in the ten top journals (Computers & Education, Digital Education Review, Cuadernos Canela, Frontiers in Psychology, and Revista Mediterranea Comunicacion—Journal of Communication with three documents each; and ARCHNET-IJAR International Journal of Architectural Research, ARTSEDUCA, Behavior & Information Technology, Computer Applications in Engineering Education,

and Computers in Human Behavior with two documents each) showed 25 out of the total sample (9.7%), reflecting the low frequency of these journals. This low percentage was linked with the ratio of articles published in this area ($p < 0.05$), which was already established by previous studies [45,77]. Despite the low presence of these journals in the sample, these were connected to other journals through bibliographic coupling (Figure 4). Moreover, the cluster formed by the top ten journals had more links and citations, as happens with the second cluster led by Computers & Education, which had 32.8% of the citations (Table 4). The citations and links could be explained because these journals are indexed in the JCR and have JCI.

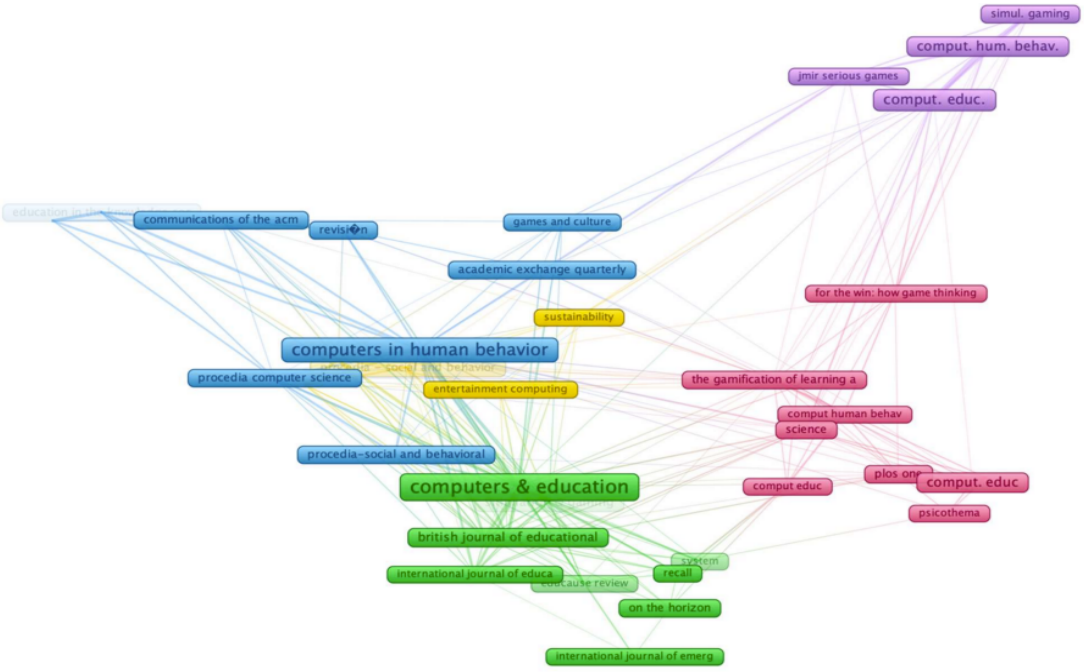

Figure 4. Co-citation between the journals.

Table 4. Co-concurrency of journals that published on this topic.

Cluster	Links between Resources	Citations	Resources with More Links and Citations	Quartile and JCR in 2020	Category of JCR
1st	117 (50%)	116 (20.2%)	Science (17 links and 13 citations)	Q1 (47.728)	Multidisciplinary science
2nd	147 (62.8%)	188 (32.8%)	Computers & Education (29 links and 90 citations)	Q1 (8.538)	Computer science, interdisciplinary applications
3rd	94 (40.2%)	142 (24.7%)	Computers in Human Behavior (27 links and 57citations)	Q1 (6.829)	Psychology, multidisciplinary
4th	65 (20.8%)	53 (9.3%)	Journal of Computers in Education (16 links and 20 citations)	-	-
5th	34 (19.0%)	75 (13.1%)	Computers in Education (12 links and 37 citations)	-	-

The results regarding the journal highlighted how much research on this topic is not published in journals, but the ones with higher relevance were available in critical journals with an association with the

STEM area, mainly the engineering field. These findings indicated that the initial publications provided contextualisation and initial input into the new technology in the education [65]. The data are in sync with other technologies applied to the medical field, whose preliminary analysis or initial developments are presented [78].

4.1.4. Determination of Sub-Topics Utilising the Keywords (RQ4 and RQ5)

The co-occurrence of index keywords was analysed using a minimum of five nodes based on 736 keywords. Through this analysis, five clusters were identified, and 37 keywords were linked (Table 5). The concurrency indicated 237 links, with a strength of 633 and 505 concurrences (Figure 5). The first cluster, identified by pink, was formed by ten keywords with 55.7% of the links and 20.2% of the concurrences of 37 keywords determined. This cluster represented one of the main sub-topic topics based on technology as a new educational paradigm. The second in green represented 24.3% of the keywords and 22.2% of concurrences, which is the sub-topic motivation and new resources for teaching, such as flipped classrooms. The third cluster, represented by blue, reflected fewer concurrences than the previous clusters (14.8%), being the sub-topic focused on game design and STEM education. The fourth cluster, being in yellow, included the keywords with more concurrences ("gamification" with 108 and "higher education" with 31). The last cluster was formed by fewer keywords (13.5%) and concurrences (7.9%) was the topic based on mobile learning.

Table 5. Main keywords used by the communities detected in the topic.

Cluster	Colour	Weight (%)	Connection between Clusters (Links per Keyword inside Each Cluster)	Keywords	Topic
1	Pink	27.0	132 (28.3%)	Students—teaching—engineering education—curricula—e-learning	Education through technological tools
2	Green	24.3	133 (28.5%)	Motivation—serious games—blended learning—flipped learning	Methodological educations impact on motivation
3	Blue	14.8	64 (13.7%)	Game based-learning—STEM-education	Gamification on STEM education
4	Yellow	13.00	86 (18.4%)	Gamification—Higher Education Institution—ICT	Gamification
5	Purple	8.97	52 (11.1%)	Mobile learning—multimedia resources	Education through mobile

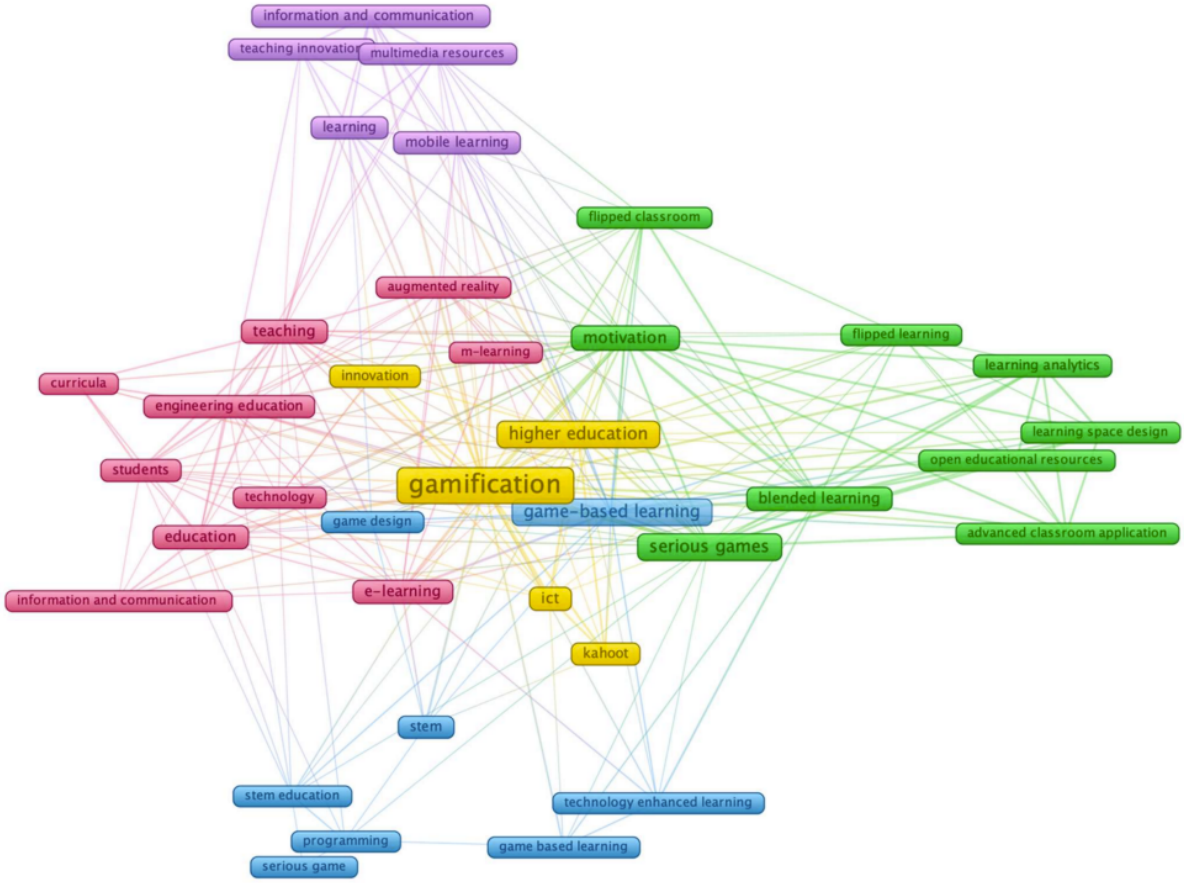

Figure 5. Co-occurrence of most common index terms per document. Note: the colours of the nodes indicate principal components of the data structure; the node size was scaled to the index keywords' occurrences.

This analysis based on index keywords has shown how gamification has a beneficial impact on motivation and education in HEIs, which matches with the recent most cited article [69]. The clusters identified highlighted the theoretical frame of the ICTs in education at the beginning of the 21st century, whose impact continues to grow and deepen their effect [76,78]. However, the negative effect of these technologies, such as tiredness or loss of performance [79], seems to be missing from the current research, whose highlights focused on the positive impact on the students [80]. This topic seems to be in sync with the Goals for Sustainability and the US Health department [23,24,28], which highlighted how the ICTs are fundamental to social and healthy environments for the students. Therefore, these results showed how the teachers' health or repercussion

from using ICTs, anxiety or burnout syndrome, seems to be overlooked in contrast with the students' [6,81]. Moreover, the inclusion of ICTs and gamification is more delimited to education, especially in the STEM field [20,71], highlighting the need for further research in other fields such as medicine or nursing [82].

4.2. Gamification in the Health Field (RQ6)

The studies focused on gamification in the health field have been analysed based on the results and the importance of gamification to improve motivation. There were 25 articles identified whose topic was gamification as a protective tool against healthcare issues, the mean of citations was 2.15 (SD = 2.05). The more frequent year of publication was 2020 (28%). The median was established in 2019, featuring 56% of conference proceedings, matching the previous results indicating how articles in this area are reduced.

Moreover, the analysis of the co-citations about these documents highlighted that the more identified journals were Computers & Education (Q1 journal and had seven citations), Safety Science (Q1 journal and had six citations), Computers in Human Behavior (Q1 journal and had five citations), and Journal of Chemical Education (Q2 journal and had six citations) with percentiles over the 70th. These results also showed again that JCR played an essential role in the publications and citations of research articles, despite being so little indexed in this sub-topic (only two were indexed in JCR).

In addition, the co-occurrence of keywords identified only four common words in one cluster. The four words were "serious games", "teaching", "students", and "engineering education", which showed how this sub-topic is underdeveloped and continues to depend on engineering courses or frameworks before developing tools or current research. This interpretation matches the results from other articles produced in 2015 and 2016 that highlighted the use of gamification in healthcare but needed further research [82,83]. Moreover, data also highlighted how the year 2020, the year of the pandemic, resulted in a decrease in publications. This could be explained, since most of the recent articles were based on the contrast of the hypothesis, which is more challenging to carry out during lockdowns [84]. In this sense, a review [84] identified 11 articles that indicated the gamification strategies used, students' assessment, and their

motivation. The articles determined that motivation increased the learning process and allowed the students to be more perceptive to the lessons [84]. These results match an escape room's initial evaluation as a gamification tool indicating their potential for teaching even postgraduate students [85]. The device was developed before the lockdowns and the experiment in Spain [85].

4.3. Implications and Limitations

This research methodology includes terms related to ICTs, gamification, and HEIs, excluding other keywords such as "schools", avoiding the possible inclusion of documents based on the topic analysed. The keywords' choice may limit the findings from the current research, since these are based on authors indexed and are not in the Medical Subject Headings. Therefore, the reduced number of articles could be explained by this selection and two databases selected (Scopus and WOS). Finally, the bibliometric analysis has a side effect, since it is based on less depth in the qualitative analysis and the overuse of quantitative metrics. Moreover, the Bibliometrix program could have been used to identify further cross-references. However, this research has intended to minimise this issue by combining various metrics, diverse metric programs, and understanding the field.

Despite the limitations, these findings have significant implications for understanding how the role of ICTs and gamification will evolve or continue in HEIs to create a sustainable and social educational environment. The results have indicated the relevant part of these technologies as motivational tools promoting healthy development from a more extended period than other studies focused on the last decade [45] or last five years [61]. Additionally, this analysis adds further information to the literature by elucidating the relevance of ICTs and specifically the gamification in HEIS and the future growth in experimental articles that could happen in the following decade [84], since most studies have presented an initial analysis [62] or review the previous studies carried out in early 2010 [65]. These results may help inform future investments in technology and education, which are more relevant now with the current pandemic, understanding the positive and negative effects of this methodology and the need for further intercontinental studies and collaborations between countries. In this sense, the bibliometric

visualisations also provide an accessible means of communicating the key findings to researchers, policymakers, and students and teachers as members of HEIs.

5. Conclusions

This paper has argued that gamification seems to be a vital tool for creating adequate and sustainable HEIs, mainly through motivation and performance improvement. This applicability and relevance of gamification can enhance the learning process in any field, resulting in more relevance for scientific areas. However, the experimental studies seem to be carried out mainly in 2018 before the pandemic in took hold in European countries. Despite the positive effect, the results have indicated that little about the side effect or long-time impact has been analysed, since most studies were reviewed, and few empirical studies have been published. Moreover, based on the keywords and topics, most studies were based on the students, overlooking the teachers. Minor studies were based on teachers in HEIs, despite the top five most cited articles showing how previous articles to 2012 focused on educators or researchers. Moreover, previous studies indicated mental issues caused by excessive or incorrect use of ICTs and gamification, which teachers have not analysed. Based on the lack of experimental studies on the medium and long-term effect and impact of gamification in teachers, especially in STEM courses, the most significant development of gamification as an ICT tool for this field is yet to come.

In conclusion, this paper presented the global research patterns and current interests and identified the areas in which gamification, especially regarding the health sector, lacks depth. Additionally, the results have highlighted the need for more studies focused on the gamification effect on teachers or academics in the HEIs, whose overload can cause mental issues. Nevertheless, more work will need to be completed to determine the grade of inclusion or usage of gamification in HEIs as promoters of a healthy learning environment.

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P.; Data Curation, P.A.-M., J.A.N.-E. and G.P.-P.; Writing—Original Draft Preparation, P.A.-M., J.A.N.-E., M.d.P.M.-J. and A.-J.P.-M.; Writing—Review and Editing, M.V.-A., M.d.P.M.-J. and A.-J.P.-M.; Visualisation, G.P.-P. and A.-J.P.-M.; Supervision, M.d.P.M.-J. and P.A.-M.; Project Administration, M.d.P.M.-J. and M.V.-A. All authors have read and agreed to the published version of the manuscript.

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Article

The Higher Education Sustainability before and during the COVID-19 Pandemic: A Spanish and Ecuadorian Case

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Abstract: Information and communication technologies (ICTs) are key to create sustainable higher education institutions (HEIs). Most researchers focused on the students' perspective, especially during the online teaching caused by COVID-19; however, university teachers are often forgotten, having their opinion missing. This study's objective was to determine the factors that contribute to the inclusion of ICTs. The research based on a comparative study through an online qualitative survey focused on the inclusion and use of ICTs in two HEIs and two different moments (pre- and post-lockdowns). There were differences regarding country and working experience ($p < 0.001$), being linked to the ICTs use, evaluation of obstacles, and the role given to ICTs ($p < 0.05$). The COVID-19 caused modifications of the teachers' perspectives, including an improvement of the opinion of older teachers regarding the essentialness of ICTs in the teaching process ($p < 0.001$) and worsening their perception about their ICTs skill ($p < 0.05$). Additionally, an initial model focused only on the university teachers and their use of ICTs has been proposed. In conclusion, the less experienced university teachers used more ICTs, identified more greatly the problematic factors, and considered more important the ICTs, with the perception of all teachers modified by COVID-19.

Keywords: education; ICTs; university teachers; sustainability; e-learning; pre- and post-lockdowns

1. Introduction

Information and communication technologies (ICTs) have taken more than thirty years [1] to be included and integrated into the daily life of individuals [2]. These technologies have achieved unprecedented inclusion and utilization, spreading to all fields in society [3–5]. The mass production and availability of ICTs have provoked modifications in social structures, from people's social networking to the educational systems [3,6]. The educational field has experienced a significant variation with the inclusion of ICTs, applying a wide range of tools, from drones, for the explanation of theoretical ideas [7,8], to virtual learning environments and virtual realities [9–12]. These tools and multidisciplinary structures have given more flexibility, adaptability, and dynamics to the education system [4,13,14]. The educational structures tend to include ICTs with a higher compliance capacity, accessibility, and end-user attractiveness. Additionally, the utilization of virtual realities via mobile devices and headsets is increasing, as they allow the immersion and acquiring of theoretical or practical skills [15–17].

However, all these technologies force the teachers of any educational level to know-how they are used, and of their benefits and shortcomings. Therefore, the teachers must adapt their profile, training, and abilities to fully integrate and utilize the ICTs in their teaching process and with the students [18–21]. It seems that the majority of authors have focused on elementary or middle educational levels, where the teachers needed to have technological and pedagogical abilities [22–24]. Nevertheless, these skills do not have to be presented among the university teachers, from lectures to professors [18,25,26]. According to García, although the inclusion of ICTs in higher educational levels, i.e., postgraduate studies, as educational innovation is a reality, this integration jeopardizes the quality of education when the university teachers have not received training about the ICTs and the teaching process [20]. In mid-2020, the pandemic of COVID-19 forced the higher institutions (HEIs) to include several ICTs and to move to online teaching, trying to guarantee the continuity and quality in their teaching process [27,28]. This shift to an online learning experience, also known as e-learning, caused the inclusion of different technologies, such as Zoom, Cisco, or Blackboard Collaborate, despite the teachers' skills and capacity to use them [10,29,30]. These modifications along the academic course and, of course, between countries or even regions can delimit the students' learning process [31]. Additionally, teachers have been forced to transform their teaching materials to an online format with little or no training or minimal prior practice [27,29]. Most teachers from HEIs were far from being prepared for

the shift to a virtual teaching–learning environment [27,29,32]. These constant adjustments regarding virtual teaching have been complex, as there was no standard paradigm and the tools were changing as time passed [10,30].

2. Theoretical Background

2.1. Sustainability, Education, and ICTs

Education plays a significant role in sustainability since it is the primary means to teach future generations, known as education for sustainability [33]. The education for sustainability focused on providing abilities and capacities for the citizens, so longterm sustained societies are possible [34]. This concept, created 30 years ago, focused on providing future inhabitants with knowledge and skills, so people are active agents in society's continuity and balance [35–37]. Moreover, quality education is essential for sustainable development in all levels of society since through it, the transformation of society is possible [36,38]. It is vital to reorientate education to develop knowledge, skills, values, and conduct to develop a sustainable society. These students will be significant agents to create and resolve the current challenges that the world faces, such as climate change, hunger, and social inequalities [33,39]. In this sense, the rapid growth of technological innovations has been welcomed as an unprecedented opportunity to address these social issues [40–42]. Teaching students in sustainable development requires that the teachers and systems are adapted to students' needs, teaching level, and modifications inside the society [37,43]. The younger generations are active users of social media, technologies, and mobile apps [40,44], implying that the systems and teachers need to include these technologies to appeal to these new generations to achieve the different skills needed in a sustainable world [45,46]. Several authors and the United Nations Educational, Scientific and Cultural Organization (UNESCO) have stated that sustainability needs to create interactive physical or virtual environments to promote quality education [33,38,39,43,47].

Moreover, UNESCO promotes ICTs as an asset to achieve Sustainable goals in different countries and emphasizes the South Hemisphere [39]. Despite the differences between developed and developing countries regarding incomes, the educational systems rely on the European countries' same structures [48–50]. An example would be Spain and other South American countries, like Ecuador, based on the same structures, laws, and principles cemented in the first legislation and created universities.

Therefore, using or utilizing ICTs could not be significantly different from Institutions with similar roots [48–50]. Because the ICTs have a crucial role in education from a sustainable perspective, most countries have integrated them into educational environments [33]. All these measurements also focused on creating sustainable institutions or green universities, with the idea of implementing and creating sustainable policies [51,52].

However, environmental education is constantly changing because of social, political, or cultural modifications [47,53]. One significant change in the year 2020 was the pandemic of COVID-19, which spread throughout the world and obliged the governments to suspend all non-essential work, including teaching [10,29]. Especially at that moment, for the education system, there was a need to train the teachers in all levels to include the ICTs and virtual education [21]. Such interactive technologies promote students' active learning, allowing their growth and independence training, and further creating networks and collaborations, among others, to solve problems [6]. Due to the relevance of their role, most studies focused on the technologies and forgot about the teachers, especially in HEIs [31,54], whose role is to create the learning and teaching environment. Nevertheless, there are still missing data about university teachers' perspectives and most ICTs or their skills to create a sustainable educational system and achieve a sustainable environment [22,23,36]. Therefore, in order to fully integrate the ICTs in the educational system for sustainability [53], it is necessary to understand the current difficulties better, the participants and willingness of the active agents, i.e., teachers, and the role of COVID-19, as an outside factor that obliged the integration [27,55].

2.2. Education, ICTs, and COVID-19

The pandemic of COVID-19 obliged countries worldwide to suspend face-to-face teaching, moving to online classes [33], putting at risk the achievement of the expectation for education according to the Goal Of Sustainability [33,38,39].

Most countries lacked resources for teachers and technological tools [56], which created difficulties for the continuation of education, its quality, and the creation of a sustainable environment [27,55]. These differences between countries were present in different continents, such as Latin America or Europe [57,58]. The report from UNESCO about education in Latin America indicated that among the countries with more resources and the possibility of live classes through online distance learning modalities were

Bahamas, Costa Rica, Ecuador, and Panama. However, the government did not provide technological devices. Additionally, other Latin countries provided technical training to the teachers or further support [57,59]. For instance, the Ministry of Education of Ecuador launched a self-learning course for teachers called My Online Classroom [60]. This same Ministry created and implemented the "Plan of COVID-19"; through this plan, the government wanted to guarantee the educational service during the phases and scenarios of health emergency; support the educational community in prevention; and provide protection and emotional support to teachers, parents, and students [58].

In Europe, the European Union put a united front to change to online teaching [61]; however, there was a lack of digital resources described as essential and widely used by the different governments to cope with this switch [62]. The different organizations around Europe have created and made available courses for training the teachers. Nevertheless, each country has put online teaching differently, including different distance learning modalities and resources for the teachers [63]. In the case of Spain, different reports have indicated that COVID-19 has increased the inequalities of equipment and preparation that exist between families, centers, and teachers. Moreover, Spain is an example of relegating the educational policies to focus on health measures; this country presents much more disparity because of diversity between territories [64]. Meanwhile, Spanish researchers have highlighted how the use of ICTs has negatively impacted teachers' health and how the students considered that the university teachers were capable and could change from face-to-face to online education [65,66]. Although few studies and reports have focused on the university level [28,67,68], the implementation of online teaching was carried out in some scenarios without training, resources, or skills, implying longer hours of working [69].

Despite the possible differences between countries or regions, Feyen indicated that the issue with COVID-19 was the pressure that the teachers at all levels may feel stress or experience some emotional distress. This stress was based on the estimation that the working hours per week with ICTs increased 20 h, being higher depending on the type of contract, working experience, age, or the country [69]. Nevertheless, these factors or comparisons between countries with similar structures or roots, such as Ecuador and Spain, with comparable ICTs and teachers' skills, have not been studied (Table 1) [49,70,71].

Table 1. Differences between Spain and Ecuador.

Differences	Ecuador	Spain
Incomes	Low-medium incomes (108.4 million in 2018)	High incomes (1.419 billons in 2018)
Dynamic transformation	Higher Education Law of 2010 to improve education and research	Organic Law 6/2001, from December 21
Number of public/private institutions	33 public/26 privates	50 public/32 privates

Following the comparison between these two countries, fewer studies are available for understanding the Ecuadorian education changes caused by COVID-19 [60,72,73]. In Ecuador, recent researches have focused on the mental health of Ecuadorian students focusing on the pressure and impact of using ICTs [72], resources available at the time [60], and the experience of the teacher [72]. In Spain publications, researchers have focused on students' perspectives regarding the change to the education, use of the ICTs, and only little has included the teachers' point of view [28,65,67,72,74]. One Spanish research had as participants the university teachers training the future teachers from elementary schools, although the objective was to evaluate the impact of ICTs on the teaching process [75].

Moreover, few studies have been based on intercontinental analysis [76–78], with only two publications studying Ecuador and Spain [77,78]. Said-Hung et al. [76], in an Ibero-America study with a sample of 700 participants from six countries, including Spain, indicated that the perception of the teachers and students depended on individual variables, such as previous experience in virtual environments or the average number of daily hours devoted to the activities, and using ICTs. Meanwhile, Tejedor et al., analyzed the perspective of 376 students from Spain, Ecuador, and Italy regarding ICTS and HEIs, and whose results indicated the need to improve the teacher's digital skills or sources for learning [77]. Another study from this same research group studied the perspective of 196 university teachers from the same three countries, indicating the lack of information, training for the new scenario, or the limited skill of technical aspects [78]. These studies pointed out how the students identified the issues regarding their educational systems and difficulties to include ICTs, therefore, to create sustainable HEIs [37,53,55,77]. However, few studies included the teachers' perspective, skills, or experience, which are major factors in providing quality education and training future generations in sustainability [50,78,79].

2.3. Hypothesis and Objectives

Because of COVID-19 and the need to continue with education, as students are the focus, teachers must have the capacity to use different ICTs and adequate resources accordingly to their needs [62]. Nevertheless, these functions and capacities are based on the teachers' training. However, as previously stated, most studies focused on students' perspectives, more commonly in secondary educational levels. Only in few cases have inter-continental studies included university teachers' perception of the challenge of virtual teaching imposed by COVID-19 pandemic [67,72,77,78,80]. Although other researchers have indicated their relevance in using ICTs in education and the impact during the pandemic [69,72], there is still missing information. In fact, many researchers do not focus on the working experience (which was already studied as a relevant factor [79]), differences between countries [78], and availability of ICTs, and much less on these agents' perspectives [22,81].

Based on the current literature, this study's objective was to carry out a comparative study focusing on the inclusion and use of ICTs in HEIs in two different countries to determine factors (i.e., working experience or availability of resources) and in two different moments at the end and beginning of the semesters. Nevertheless, an unexpected event occurred during this research, which was the global pandemic, implying the need to include another factor, COVID-19. Furthermore, two hypotheses were established from the previous literature:

Hypothesis H1. There is an association between ICTs use, skills, the obstacle for integration, and the country. Hypothesis

H2. There is an association between working experience and the use of ICTs, skills, and importance given to the ICTs.

3. Materials and Methods

3.1. Survey Data Collection

The present research studied the university teachers' perspective regarding the ICTs skills, the relevance of the ICTs, frequency of using ICTs to create a sustainable system, the impediments that make the inclusion of ICTs difficult, and the impact of COVID-19. Two descriptive, exploratory, and cross-sectional studies applied to comparative analysis between Spain and Ecuador were carried using a reference population of university teachers in two different set times. The set times were selected based on the final and beginning of the semester; the first survey was distributed in December 2019

and opened until January 2020, previous to the pandemic. The second time the survey was distributed between September and opened until October in 2021, after the first lockdown and quarantine of the countries.

An incidental non-probabilistic sampling, widely used in research because of the simplistic implementation [66], was used for this research. First, the selection of the universities was based on accessibility, availability in both time sets, and relevance according to the position in the international ranking for Universities. Eight universities were selected (two from the top including Polytechnic of Valencia, two from the middle including the University of Seville, and two in the bottom, including Cordoba and Ecuador since both are more recently created) [82].

The Spanish university teachers invited to participate were from the Engineering School, and the Ecuadorian teachers were from the Communication and Engineering School. The selection of this sample was based on previous studies that indicated how teachers from a more technological background seem to have more ICTs skills [12,83,84] and how the Ecuadorian teachers' ratio seems to be higher than Spanish [85]. The university teachers were contacted through email, by which the information (like objectives and type of study) was explained, and they were asked for their willingness to participate. After receiving positive feedback, the willing participants received the link to the survey. They were encouraged to spread the survey among other colleagues from the same area and center, obtaining an anonymous and random sample. Based on previous intercontinental studies [78] and an estimated five percent response rate [86], the sample calculation was carried out. Based on the sample of university teachers from the institutions selected and accepting an alpha risk of 0.05 and a beta risk of 0.2 in a bilateral contrast, 43 subjects are required in the first group and 43 in the second to detect as statistically significant the difference between two proportions, which for group 1 is expected to be 0.36 and group 2 of 0.66 (or vice versa group 1 0.66 and group 2 0.33).

The total sample was teachers from three Spanish (Cordoba, Seville, and Valencia) and one Ecuadorian HEIs, with a higher rate of response among Ecuadorian teachers (as the median the number of fully responded in the survey was set at 24) than Spanish (as the median the number of responses was set at 20). The number of university teachers that responded to the survey for the first time was 51, increasing to 55 university teachers after the lockdowns. Only 44 university teachers responded fully to the survey before the pandemic and after the lockdowns, being identified through the

computer's IP, which was later codified following the ethical and privacy codes [87]. This study was conducted using a questionnaire completed online, which was the optimal methodological mechanism to collect information.

3.2. Instruments

This study was implemented using a questionnaire transformed into online surveys distributed through QuestionPro (Survey Analytics LLC, San Francisco, CA, USA). The survey was formed by 11 items, selecting one answer, and based on the Likert scale from 0 (total disagreement) to 5 (Total agreement) (Table A1). The survey was structured in four segments: the information sheet, the objective, ethical code, confidentiality, and anonymization. After accepting to participate, the volunteers accessed the central section, leaving some items unmarked or dropping out at any moment. The main section was the teachers' opinion about ICTs and their inclusion in the education field in higher education, from which the data was obtained. The items were country, working experience, ICTs skills, frequency of using more ICTs for different educational purposes, the evaluation of obstacles, the evaluation of the ICTs role in the learning process, the relevance is given to ICTs as an essential key for the educational structure and how no clear evidence of educational changes is an obstacle for integrating ICTs. The validity, reliability, and consistency were studied for the survey. The validity was calculated through Pearson's correlation, indicating that all items were valid ($p < 0.001$), except for the availability of software and the internet ($p > 0.05$). The reliability statistics were applied to the survey items, showing really good reliability of the test to measure the workers' perception (Cronbach's Alpha = 0.81; Corrected item > 0.4; ANOVA Cochran's Q = 178.13, $p < 0.001$). Moreover, the Hedges' g was used to determine the size effect of the samples regarding the working experience (0.23), essentialness of ICTs (0.19), the availability of resources (0.33), lack of resources (0.41), ICTs skills (0.84), and the role of ICTs in the teaching process (0.89).

The participants received an email in which they were informed about the survey's objectives, the time allowed to complete it (10 min), the voluntary nature, and the possibility of not completing it. This survey also included a section where the participants had to give their consent before completing it. The exclusion criteria were teachers from different educational levels. The data was organized using the identification given to the participants based on their IP direction.

The programs used were Excel version 2017 (Microsoft Corporation,

Redmond, WA, USA) and SPSS program version 25 (IBM SPSS Statistics) for the statistical analysis. All data were saved in a cloud available only to the researchers.

3.3. Procedure

Teachers approved a participant information statement, consent form and accessed questionnaires through the online version. The information statement included the study's objective, the explanation of the survey, the voluntary and consent to participate, and anonymity after agreeing to fill the survey through an option of "Yes/No," passing to the questionnaire, completing it partially or entirely, or to the acknowledgments. This informed consent followed the fundamental principles established in the Declaration of Helsinki of 1964, the World Medical Association, subsequent amendments, and the 1996 Council of Europe Convention on Human Rights and Biomedicine and the Data Protection Law 3/2018 5. Moreover, this study did not include any medical information focusing on the academic's opinion, though it was in line with a project on Occupational Safety that received Ethical Research Approval (Reference 4258).

3.4. Statistical Analysis

The survey was completed by 51 teachers in the first period, although a variable was indicated as not completed or rather not say. The second time the survey was fully completed by 55 teachers. For both samples set in different periods, the qualitative variables were studied using frequencies (absolute and relative) and the median with their 95% confidence intervals (CI). The Kolmogorov–Smirnov test and the Shapiro–Wilk test were applied, indicating that the data did not follow normality ($p < 0.001$). The chi-test, Kendall's tau-b, Cramer's V, McNemar test, and Spearmen's correlations tests were applied accordingly in both samples. The university teachers belong to different centers had diverse working experiences. Additionally, a sample of 44 participants that fully completed the survey both times, according to id, were statistically analyzed to determine the impact of COVID-19. The median and frequencies and IC% 95 were used; and the no-parametric tests for independent variables were applied to determining differences, such as chi-test and correlations. Based on two different periods (pre- and post-lockdown), the non-parametric repeated measures taken over time, specifically the mixed-model analysis of variance (ANOVA), were used to determine the modifications in ICT implementation using simultaneously

country, preand post-lockdown, and experience as independent variables. Multiple linear regressions were carried out.

4. Results

4.1. Results Previous the Pandemic

The initial analyses of the university teachers' perspective before the pandemic in Spain and Ecuador were analyzed to determine differences inside the sample (Table 2). The analysis showed significant variances between the Spanish and Ecuadorian samples for teaching at different levels ($X2 = 5.76$; $p = 0.02$) and the working experience ($p < 0.05$). The availability of ICTs (computers, software, virtual environments, and the internet) and skills did not show significance between both countries (Table 2). Additionally, the perception of the essentialness of ICTs in the teaching process was significantly different among countries ($X2 = 6.52$; $p = 0.04$).

Table 2. Descriptive of the variables accordingly to the country.

Factors		Before the Pandemic (N = 51)		
		Spain (41.2%)	Ecuador (58.8%)	*p*-Value
Teaching at different levels	Undergraduate	61.9%	90.0%	0.016
	Postgraduate	38.1%	10.0%	
Working experience	Less than ten years	23.8%	53.3%	<0.006
	Between 10 to 20	19.0%	23.3%	
	Between 20 to 30	23.8%	16.7%	
	More than 30	33.3%	6.7%	
	Rather not say	1.2%	5.9%	
Availability of ICTs	Nothing	10.7%	10.9%	0.12
	Little	10.7%	20.0%	
	Enough	29.8%	21.7%	
	A lot	47.6%	41.7%	
ICTs skills	Little	0%	0%	0.59
	Enough	14.3%	6.7%	
	Many	52.4%	63.3%	
	Outstanding	33.3%	30.0%	

The Ecuadorian participants were more likely to teach to undergraduate students ($\rho = -0.34$; $p = 0.02$) and have less working experience ($\rho = -0.39$; $p = 0.003$). These participants indicated with more frequency that the role of ICTs in education was essential ($\rho = -0.49$; $p < 0.001$). The working experience was studied since it has a great significance and seemed to be a vital factor in its integration and use. The 66.7% of the sample had less than twenty years of working experience, being present significant differences according to the essentialness of ICTs ($X2 = 15.73$; $p = 0.04$). The median was set in between ten and twenty years, and the working experience was studied using the median as a breakpoint. Less than twenty

years of working experience, independently from the country, was associated with using more frequently the ICTs for researching (ρ = −0.32; p = 0.01) and for pedagogic purposes (ρ = −0.36; p = 0.009) (Figure 1).

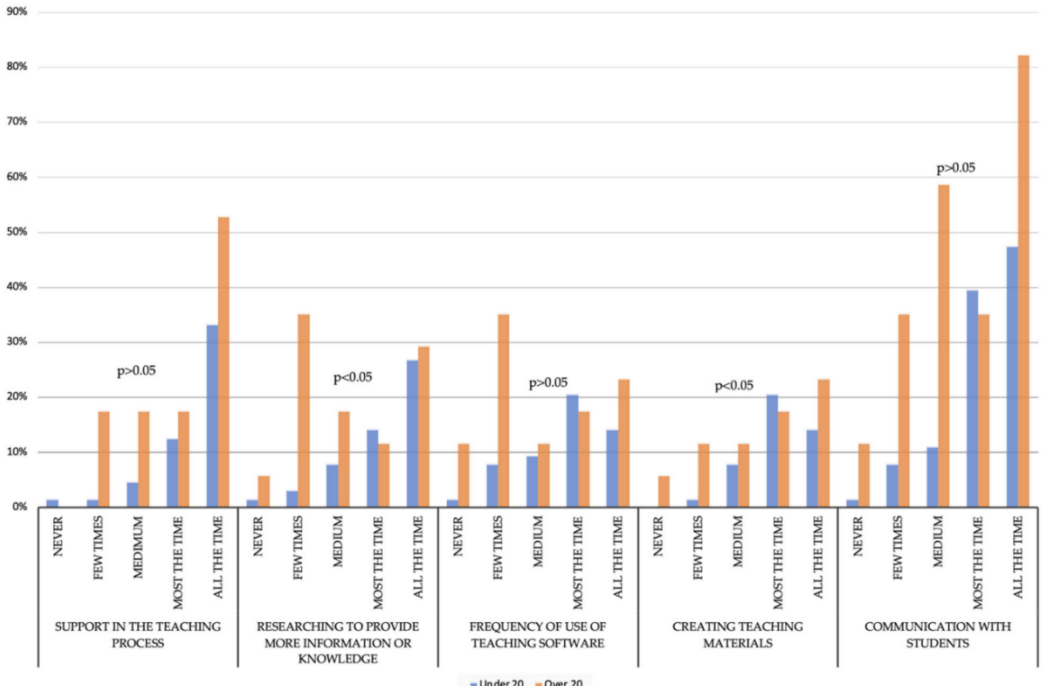

Figure 1. The opinion of university teachers about the frequency of ICTs utilization based on the breakpoint of twenty years of working experience.

There were also significant differences between university teachers with less than twenty years of working experience regarding their opinion of the relevant role that may have ICTs in the learning process (X 2 = 6.75; p = 0.03). In this sense, teachers with less working experience seemed to give more relevance to the role of ICTs (ρ = −0.35; p = 0.02). The factors that may impede the teaching process and the integration of the ICTs were studied according to working experience. The workers under 20 years of experience indicated that insufficient resources (17.6%), software or educational programs (26.5%), educational training (32.4%), educational models (29.4%), and time (34.9%) were essential as obstacles. In contrast, the workers over 20 years of experience said that insufficient resources (21.6%), software or educational programs (27%), educational training (26.4%), educational models (31.6%), and time (32.5%) were considered necessary as obstacles.

The associations between the working experience were carried out for each obstacle, indicating associations between younger working experience and higher consideration of the obstacles, being only significant for

educational models (ρ = −0.35; p = 0.02). Finally, the segmentation accordingly to working experience was studied for no clear evidence of educational changes is an obstacle for integrating ICTs, showing no significant differences (p > 0.05). 4.2. Results Post-Lockdown Caused by COVID-19 The data of the university teachers after the lockdown in both countries was analyzed (Table 3). The results indicated significant differences between countries for teaching at different levels (X2 = 4.85; p = 0.03) and the working experience (p = 0.003). The availability of ICTs (computers, software, virtual environments, and the internet) and skills did not show significance between both countries (Table 3). Meanwhile, the perception of the essentialness of ICTs in the teaching process indicated significant differences (X2 = 17.87; p < 0.001). Moreover, the correlations highlighted how Spanish university teachers from Ecuador seemed to be more likely to have less working experience (ρ = −0.39; p = 0.003) and more frequently have considered the role of ICTs in education was essential (ρ = 0.55; p < 0.001).

Table 3. Descriptive of the variables accordingly to the country.

Factors		Post-Lockdown (N = 55)		
		Spain (32.7%)	Ecuador (67.3%)	*p*-Value
Teaching at different levels	Undergraduate	66.7%	67.6%	0.03
	Postgraduate	33.3%	24.3%	
Working experience	Less than ten years	22.2%	40.5%	<0.001
	Between 10 to 20	11.1%	35.1%	
	Between 20 to 30	22.2%	18.9%	
	More than 30	44.4%	5.4%	
Availability of ICTs	Nothing	11.9%%	6.75%	0.5
	Little	6.9%	8.8%	
	Enough	27.9%	16.2%	
	A lot	53.3%	68.3%	
ICTs skills	Little	0%	0%	0.12
	Enough	27.8%	16.2%	
	Many	66.7%	54.1%	
	Outstanding	5.6%	29.7%	

The Ecuadorian university teachers were more likely to consider a more active role of ICTs in education (ρ = 0.36; p = 0.006), use more frequently the ICTs for researching (ρ = −0.29; p = 0.03) and pedagogic purposes (ρ = 0.38; p = 0.005), considered that the lack of resource, software, pedagogic training, and models were vital factors of the integration of ICTs (p < 0.01). The working experience was studied since it has a great significance and seemed to be a key factor in its integration and use. Workers with less experience were more likely to be from Ecuador (ρ = −0.39; p = 0.003), considered more essential role of ICTs (ρ = −0.51; p < 0.001), give a more relevant role to ICTs (ρ = −0.37; p = 0.01), considering an obstacle the lack of

resources (ρ = −0.28; p = 0.04) and lacking pedagogic training (ρ = −0.28; p < 0.001). A total of 61.8% of the sample had less than twenty years of working experience, being present significant differences according to the essentialness of ICTs (p = 0.03). The median was two representing the range from ten to twenty years. Less than twenty years of working experience, independently from the country, was linked to considered ICTs essential (ρ = −0.47; p < 0.001), the role given ICTs (ρ = −0.32; p = 0.02) using more frequently, the importance given to the lack of resources (ρ = −0.35; p = 0.009), pedagogic training (ρ = −0.32; p = 0.02) and models (ρ = −0.32; p = 0.02), as obstacles to integrating the ICTs in the education.

4.3. Comparison Pre- and Post-Lockdown

The number of university teachers who completed both surveys, pre- and post-lockdown, was 18 from Spain and 26 from Ecuador, teaching 66.7% of the Spanish and 88.5% of the Ecuadorian undergraduate students. There were no significant differences between the two times and between countries (p > 0.05). The 88.4% of Ecuadorian teachers had less than twenty years of teaching experience (61.5% less than ten years and 26.9% between ten and twenty); meanwhile, 66.6% of Spanish usually had a minimum of 20 years (44.4% with than 30 years) (p < 0.001). The working experience hardly changed from the pre and post-lockdown, changing 4.5% of the university teachers. This working experience was linked to the essentialness of ICTs pre- (ρ = −0.65; p < 0.001) and post-pandemic (ρ = −0.39; p = 0.003), being the younger teachers, the ones who considered more highly the ICTs. Additionally, the working experience was linked to the importance given to the role of ICTs in the teaching process only pre-lockdown (ρ = −0.58; p < 0.001). The working experience was associated with the frequency of using ICTs for different purposes for creating teaching materials (ρ = −0.35; p = 0.04), increasing the frequency of use of the ICTs in the IC 95% from 5.2% to 8.9% (Figure 2). In general, the frequency of always using the ICTs was 39.7% (95% CI 32.3–44.6%) before the lockdown and 46.8% (95% CI 42.4–51.3%) after the lockdown.

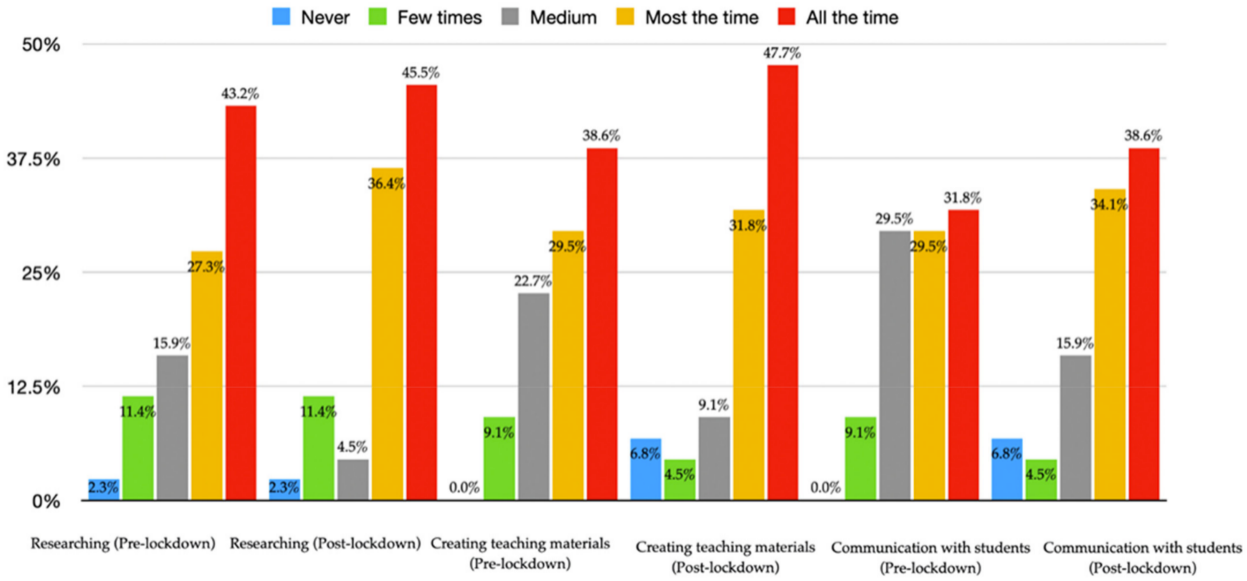

Figure 2. The opinion of university teachers about the availability of resources pre- and post-lockdown.

Since the sample was segmented mainly by having more or less than 20 years of working experience, this cut point was analyzed for the frequency of using ICTs before and after the lockdown, the availability of ICTs, ICTs skills, and perception of the obstacles. The ICTs utilization to support the teaching process through programs for designing content, researching to provide more information, creating innovative or interactive teaching materials, and communication with students indicated differences regarding the working experience and the two-time sets (Table 4). This table indicated that the university teachers with less working experience frequently used the ICTs after the first lockdown for researching to provide more information, create innovative or interactive teaching materials, and communicate with students ($p < 0.05$). Additionally, the workers with less experience indicated that the use of ICTs increased after the lockdown for researching to provide more information or knowledge ($\rho = -0.36$; $p = 0.02$) for creating teaching materials ($\rho = -0.43$; $p = 0.007$) and communication ($\rho = -0.54$; $p < 0.001$).

Table 4. Symmetric measures of the working experience and frequency of using the ICTs in the two-time sets.

Resources	Pre-Lockdown		Post-Lockdown	
	Under and Above 20 Years of Working Experience	*p*-Value	Under and Above 20 Years of Working Experience	*p*-Value
Support in the teaching process	−0.21	0.15	−0.22	0.16
Researching to provide more information or knowledge	−0.24	0.82	−0.34	0.02
Teaching software	−0.19	0.19	−0.18	0.15
Creating teaching materials	−0.16	0.36	−0.39	0.007
Communication or collaborative tool	−0.15	0.29	−0.49	<0.001

Additionally, the mixed ANOVA test was calculated for the two-time sets, the working experience, and the frequency of using the different resources. The results indicated that the interaction of these variables was not significant (p = 0.13), but there were significant differences between the frequency of using ICTs and working experiences (mean difference = 0.74; p > 0.001), making it more significant after the lockdowns (Figure 3).

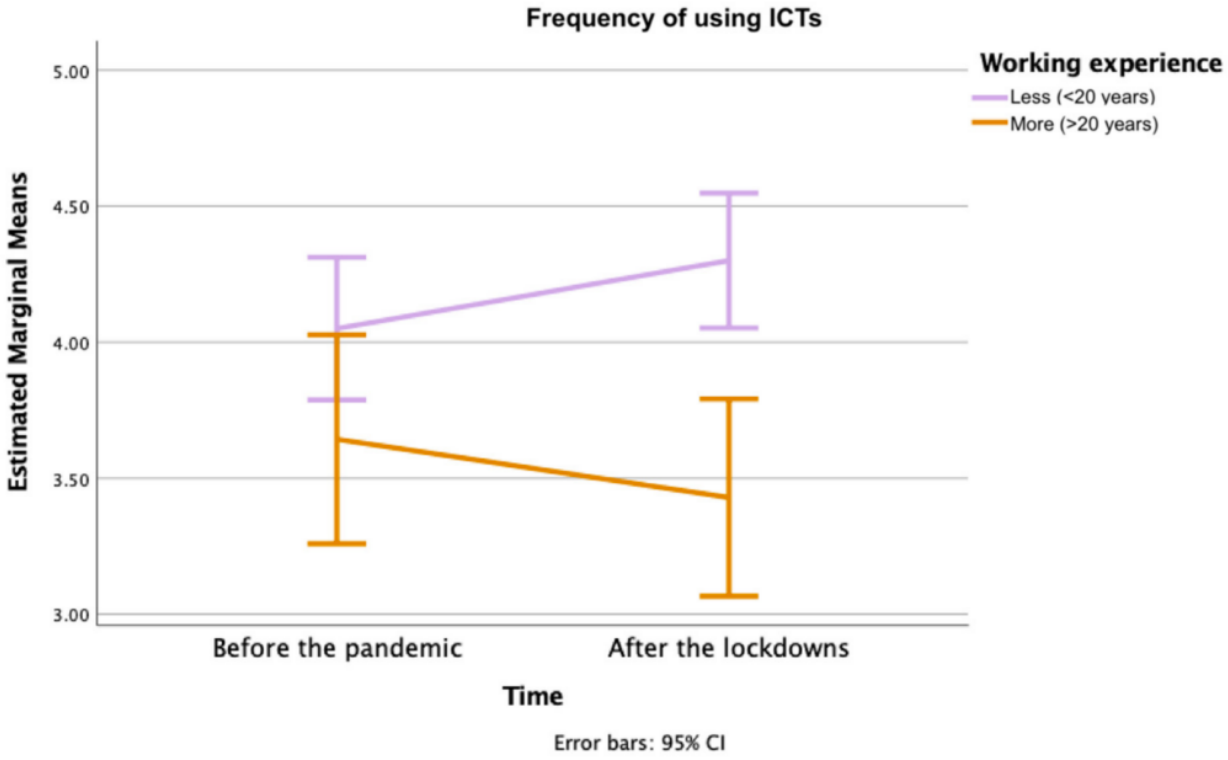

Figure 3. Frequency of using ICTs according to working experience and the two periods of time.

The working experience was also studied for ICTs' essentialness in the two-time sets. The difference between the working essentialness and

two-times sets was significant (p = 0.64), although when analyzed the working experience, essential, and both time sets, there were significant differences (sum of squares = 1.6; p < 0.006). The essentialness of ICTs for less working experience was almost the same before and after the lockdowns. In contrast, university teachers with more working experience indicated an increase in the essentialness of the ICTs. Their perception changed from answering No (35.7% before and 7.1% after the lockdowns) to Maybe or Yes (28.6% before and 57.1% after the lockdowns). The working experience was linked to the ICTs skills, improving the perception of ICTs skills among the workers with less experience by 10% and worsening in older workers (10% considered enough before the lockdown and 35.7% after the lockdown). However, there were no significant differences between pre- and post-lockdown (p > 0.05).

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The working experience was linked to the ICTs skills, improving the perception of ICTs skills among the workers with less experience by 10% and worsening in older workers (10% considered enough before the lockdown and 35.7% after the lockdown). However, there were no significant differences between pre-and post-lockdown (p > 0.05).

Moreover, the mixed ANOVA, using the ICTs skills related to the two-time sets (before and after the lockdown) and the working experience, was carried out. According to the univariant model, the analysis indicated significant differences within-subjects (p = 0.003) for the working experience and ICTs skills. However, the time with ICTs skills combined with working experience was not significant (p = 0.78). The correlations showed that less working experience was linked to indicating more commonly to have outstanding skills before (ρ = 0.37; p = 0.013).

The workers with less than 20 years of experience indicated that insufficient resources (20.0% before and 56.7% after), software or

educational programs (20% before and 60.0%), educational training (30% before and 63.3% after), educational models (40% before and 53.3% after), and time (36.7% before and 50% after) were essential as obstacles. The workers over 20 years of experience said that insufficient resources (21.4% before and 14.3% after), software or educational programs (21.4% before and 7.1% after), educational training (21.4% before and after), educational models (14.3% before and after), and time (21.4% before and after) were considered necessary as obstacles. The associations between the working experience for this segmentation were carried out for each obstacle before and after the lockdown (Table 5), indicating associations between younger working experience and higher consideration of the obstacles mainly after the lockdown (insufficient resources, educational training, educational models and time) ($p < 0.05$).

Table 5. Symmetric measures of the working experience and the factor whose lacking difficulty the teaching process in the two-time sets.

Resources	Pre-Lockdown		Post-Lockdown	
	Under and Above 20 Years of Working Experience	*p*-Value	Under and Above 20 Years of Working Experience	*p*-Value
Resources	−0.03	0.84	−0.38	0.003
Software	−0.12	0.43	−0.46	<0.001
Educational training	−0.17	0.21	−0.39	0.002
Educational models	−0.30	0.03	−0.43	<0.001
Time	−0.23	0.11	−0.29	0.03

The results of the ANOVA test for lacking ICTs (resources, software, educational training, models, time, and no research about the clear benefits) in both times and related to the working experience indicated no significant differences for lacking ICTs and the working experience (Table 6). The working experience and the perception of lacking ICT indicated differences between group through the univariant tests (sum of squares = 6.4; $p < 0.01$).

Table 6. Pairwise comparison between the period, lacking ICTs, and working experience.

Lacking ICTs	Sum Square	*F*	*p*-Value
Time (Pre and post-lockdowns)	0.87	1.9	0.28
Time*Working experience (Breakpoint 20 years)	1.96	2.69	0.11

Additionally, the differences between before and after the lockdown for each variable were studied. The working experiences and the teaching at different levels did not suffer significant modifications between the two time sets ($p > 0.05$). The availability of resources (like virtual laboratories or environments, computers, or internet access)

changed accordingly to each time set, improving university teachers' perception except for software (Figure 4). Additionally, the associations indicated a significant difference between preand post-lockdown in the case of VL virtual laboratories (VL) ($\rho = 0.27$; $p = 0.049$), being not significant for the other assets ($p > 0.05$).

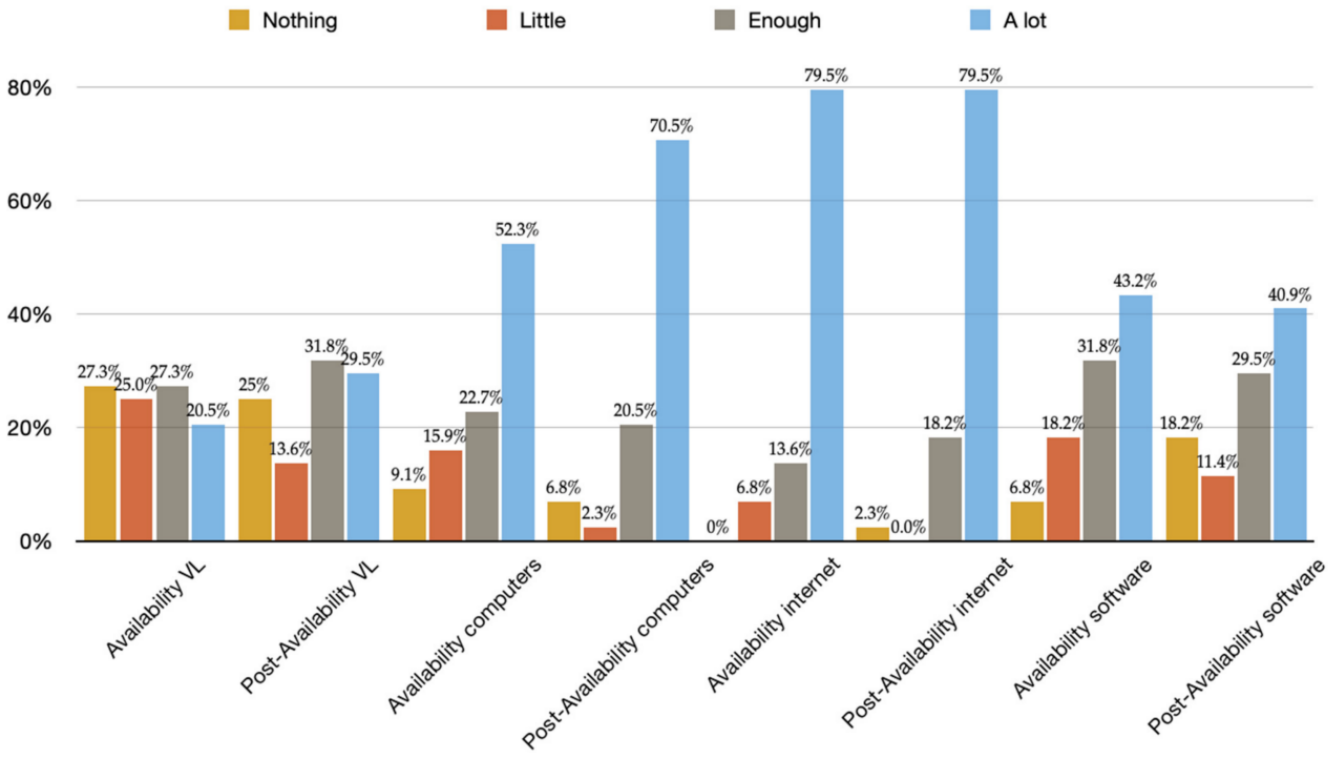

Figure 4. The opinion of university teachers about the availability of resources pre- and post-lockdown.

Moreover, the ICTs skills changed from before to after the lockdown, indicating that 4.6% of the university teachers believed they had better ICTs skills after the pandemic. Although, the change was not significant between the pre and after-the-lockdown for the ICTs skills ($p = 0.9$). ICTs skills before and after the lockdown were associated with the essentialness of ICTs ($\rho = 0.33$; $p = 0.03$), frequency of using them ($\rho = 0.41$; $p < 0.01$), and the importance of their role ($\rho = 0.3$; $p = 0.03$). Additionally, the ICTs skills after the lockdown were linked to the frequency of using the teaching software ($\rho = 0.49$; $p < 0.001$), lacking resources ($\rho = 0.33$; $p = 0.03$), and lacking evidence regarding the beneficial role of ICTs in the education ($\rho = 0.30$; $p = 0.03$). Based on the data, the university teachers' opinions were further studied using the multiple linear regressions having a dependent opinion about skills. The results showed that the ICTs skills

before the lockdown were linked to ($R2 = 4.76$; $p < 0.001$) the essential of the ICTs ($p = 0.013$) and the frequency of using the ICTs for teaching ($p = 0.009$); and after the lockdown ($R2 = 6.53$; $p < 0.001$), it was linked to the frequency of using the ICTs for researching($p < 0.001$), lack of resources ($p = 0.017$) and lacking software ($p = 0.023$).

5. Discussion

The initial results according to country showed that the university teachers' perspective differed from the country (Ecuador and Spain), which is highly important for their perspective the working experience and the different time sets. Based on these results, the first hypothesis was tested as affirmative, which is crucial to achieving sustainable educational institutions. The difference between working experience could also imply that younger university teachers should receive further pedagogic training or make available models focused on ICTs inclusion to achieve sustainability in higher education. These results corroborate the findings of a great deal of the previous work that indicated how working experience, and possibility the of the workers' age [88], is a major factor in the ITCs skills [79], is also highly evaluated in this university teachers with an engineering background [65,89].

Several countries have integrated new reforms to renew the staff, gathering younger and further trained university teachers, all of this to achieve a sustainable educational institution [73]. These measures are based on creating activities related to the facilitation of decision-making and implementation of sustainability policies [90,91]. Moreover, following the present results, previous studies have demonstrated that difficulties in achieving sustainable educational institutions continue to be presented [92], and these organizations should move towards sustainable goals [93]. Nevertheless, most studies focused on the students as the most significant agents, integrating the new educational models accordingly o their age [14,73,94]. Despite that, Freidenfelds et al. [92] indicated that sustainable goals should focus on the stakeholders, students, researchers, and staff, being optimal to understand the teachers better.

The pre-lockdown results indicated how the university teachers' perception about accessibility to ICTs for teaching purposes was poor, improving after the first lockdowns (computers, internet, and VL) except for specific teaching software that worsens. This outcome is contrary to Tejedor et al. [78] (2020), who found that the university teachers found a

lack of resources after the pandemic of COVID-19. However, this study only focused on post-lockdown. Therefore and no prior study has described it, these unexpected results could indicate how the perception of the availability of ICTs, including access, proper amount, and the correct type of technology, depends on the user's need and the specific moment [89,95]. Additionally, these results could be linked to the modifications of the teaching paradigm based on face-to-face classes to an online or virtual teaching method [10,28]. Another possibility is that participants' perception depends on external factors that may improve or deteriorate their opinion, explaining the changes of opinion before and after the lockdown regarding the availability of ICTs, ICTs skills, and the importance of different obstacles [96,97].

The ICTs skills were linked in the pre- and post-lockdown to whether the university teachers considered that the ICTs had an active role in the teaching-learning process. These results synced with previous studies that how the participants' opinion about the importance of ICTs is key to the correct integration of such technologies [38]. These associations might result from the need to integrate, create, and adapt to a teaching paradigm based purely on online teaching [22,34]. An unexpected result was that despite having to integrate an online learning process, the ICTs' frequency of use, according to university teachers, did not significantly increase after lockdowns. These results matched the finding of other authors, whose results about e-learning teaching did not increase the technologies [98]. An explanation of this could be linked to the training and ICTs skills of university teachers. In sync with this, Achard indicated how depending on the training of the teachers, online teaching did not imply more difficulties or a higher frequency of using ICTs, even though the pandemic has imposed the active role of integrating the ICTs in education to the teachers [99]. Another factor evaluated by the teachers was the essentialness of the ICTs in the teaching process. In this case, both Spain and Ecuador considered that the ICTs in education were essential before COVID-19 and after the lockdowns, showing no initial significant differences. These results could be due to the integration of ICTs daily and the importance given by different governments [37] and organizations worldwide [33,100,101]. Such relevance has been sustained during the pandemic on the efforts of the teachers and students [102]. Nevertheless, an unexpected finding was the changes of the opinions regarding the essentialness of the ICTs in the teaching process, which was related to

thdifferences in time-sets and working experience. This perception drastically changed from before the pandemic and after the lockdowns, increasing older workers. Such findings could be caused by the obligatory use of ICTs for online teaching and along with the necessary understanding, skills and resources. Although these results were not previously found, this outcome seems to be in sync with previous research that indicated how the frequency of using ICT determines the importance and relevance given in [12,47].

The previous statements and the Sustainable Development Goals focused on the 4th Quality of Education [38]. It highlighted the need of improving university teachers' training or ICTs skills and renewing the institutions with younger university teachers. This approach could be more effective than providing more ICTs, which could be a pivotal task to achieve a sustainable educational system. This goal is more urgent than ever, as there has not been a previous moment in modern history with so many students suffering a disruption of their education [34]. Therefore, and based on the results, an initial model focused only on the university teachers as active agents and their use of ICTs has been proposed (Figure 5).

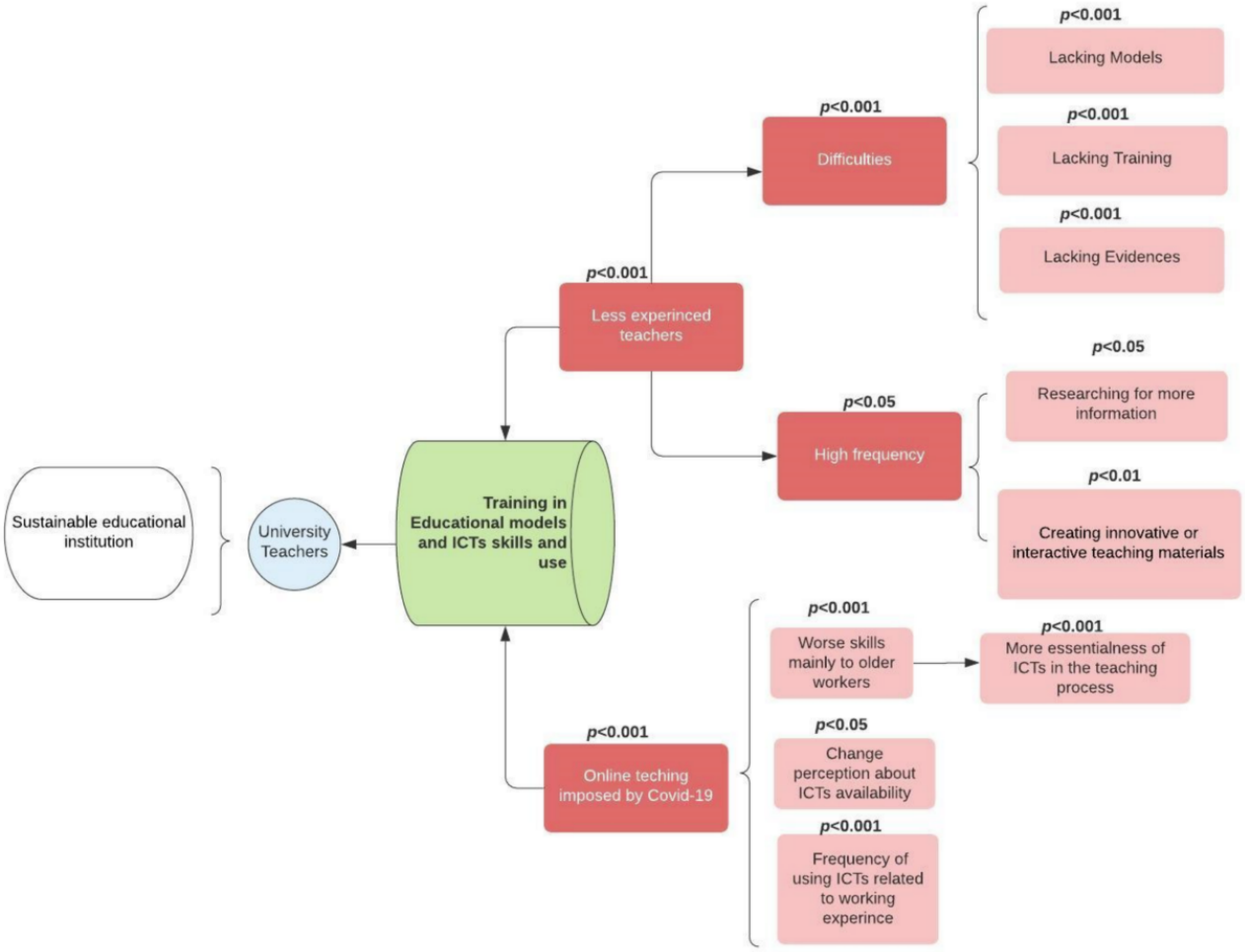

Figure 5. The model focused on university teachers for achieving a sustainable educational institution.

Figure 5 indicated that achieving sustainable educational institutions requires understanding of the roles of the university teachers and how it is imperative to provide training in regard to models that integrate the ICTs and improve the ICTs skills and their use. Additionally, the model, based on the results, highlighted the importance and difference about working experience, the relevance of the lack of models, training, and evidence as obstacles for integration ICTs. Finally, this figure indicated that the change to online teaching improved the availability of resources (VL) and the opinion of older workers regathe essentialness of ICTs in the teaching process. However, it also worsened the ICTs skills in older workers. This figure shows the need to train the university teachers, but there is a need to adapt it mainly to the working experience and the

population's perception.

6. Limitations and Implications to the Field

The current study, as any research, has some limitations. The major limitation of this study was the small sample of the university teachers participating in the study, being similar to the estimation, but it continues to be rather small. This research has obtained the data of university teachers' views using an observational method that has limited such results to the countries that have participated and the timeframe used. The survey data is based on people's opinions with a transversal cut, and it would be wise not to apply all the variables linked to other populations or in different set times.

Despite the limitations, the current study presents interesting qualitative data from a hardly studied group from HEIs, providing more evidence about how COVID-19 has modified the educational system and its sustainable capacity. Moreover, this approach was not being taken previously, as most studies focused on establishing the impact of COVID-19, the sustainability of the educational systems mainly in primary or secondary education, and did not include the perception in different moments, including personal factors such as working experience. Only one study at the intercontinental level studied the teachers' perspective, being limited to the lack of resources [77]. Despite being limited to two periods of time and two countries, the results presented in this paper could be used to illustrate the relevance of university teachers' views regarding ICTs as significant agents in creating sustainable educational systems and adapting to changes and requirements from society.

7. Conclusions

This paper has argued how integrating the ICTs in the education system is key to creating sustainable education institutions, being highly important for the benefit of the university teachers, their ICTs skills, and the impact of COVID-19.

The initial results according to country showed that the point of view seemed to differ for the Ecuadorian and Spanish university teachers, with the variation linked to their working experience. In this sense, the less experienced university teachers spent more time using the ICTs, identified more greatly with the problematic factors, and gave a more critical role to the ICTs independently from the country or the time set. Moreover, the

results focused on comparing the pre- and post-lockdown indicated how despite having the availability of ICTs, the younger university teachers considered that there were not enough ICTs and that their skills were highly superior. Additionally, the university teachers with more experience had a change of their perception regarding the essentialness of the ICTs for the teaching process, considering them as more important after the lockdowns. Therefore, the pandemic of COVID-19 and posterior lockdowns seemed to have a major role in changing the perception of these agents in the sustainable educational system, which could be the missing piece for the complexity of full integration of ICTs.

Since the university teachers' perspective were little studied, an initial model has been presented. This model presents how the major key points seem to be linked to age and the imperative of online teaching, focusing on training university teachers in educational models and ITCs skills and how to use these. Nevertheless, there continues to be a need for further research focusing on ICTs, education, and skills, and university teachers' perception as a unit to achieve a sustainable approach about education as a pillar for both the sustainable education system and education for sustainability. Therefore, forthcoming research should focus on creating educational interventions based on providing more training, determining educators' opinions regarding lack of resources and frequency of using ICTs in HEIs

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Moreover, the study was conducted according to the guidelines of the Declaration of Helsinki.

Data Availability Statement: The data is available, please contact the authors.

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Appendix A

Table A1. Structure and items of the survey

Questions	Specifications of Each Question	Answers
Country that you are currently working:	None	Spain Ecuador Other
Level at which you teach	Selected the one according to teaching hours per week	Undergraduate Postgraduate
Working experience at the University level:	None	Less than one From one to ten years From ten to twenty From twenty to thirty More than thirty
Availability of resources (ICTs) Indicate the availability of the following resources for your classes of the subject:	0 Rather not Say/Not Known 1 Nothing (No Availability) 2 Little 3 Enough 4 A lot	Virtual laboratories or environments Computers Internet connection Software
ICTs skills Indicate what you think is your level of competence in the management of ICTs or ICTs skills according to the following scale:	1 No skill	Lowest as no user
	2 Little	
	3 Enough	
	4 Advance or oustanding skills	User of ICTs for design and multimedia or multiplatform tool
Essentialness of ICTs in the teaching and learning process:	Do you think that the skills and procedures used with ICTs are essential for learning the subject	Yes No Maybe

Table A1. Cont.

Questions	Specifications of Each Question	Answers
Frequency of using ICTs Indicate the frequency of using ICTs according to working hours per week	1 Never 2 Sometimes (less than 25% of working hours) 3 Usually (50% of working hours) 4 almost always (more than 75% of working hours) 5 Always 0 Rather not say/Not known	In general As a tool to support the teahing process (e.g., presentations, notes, web pages, digital whiteboard...) To search for information or to carry out exercises to extend/reinforce the theory (consultation on web pages, databases, encyclopedias and specific software, tutorials, self-assessment questionnaires...) For the realization of laboratory practices and development of skills of experimental work through specific software (computer-assisted laboratory; virtual laboratory; databases...) For the elaboration of further teaching materials (documentation works; WebQuest; preparation of presentations...) As a means of communication or collaborative learning (forums, distribution lists, chats, wikis, blogs, classroom projects...)
Role of ICTs in the teaching process	Do you think that the use of ICT can contribute to the learning of skills and procedures in teaching the subject?	Yes No Maybe
Importance given to the lack of resources Evaluate the importance for you of the following obstacles to the incorporation of ICT in the realization of experimental work with students:	1 Does not Constitute an Obstacle 2 Not very Important 3 Important in some cases 4 Quite Important 5 Very Important 0 Rather not say/Not known	Lack of resoruces in general (computers, internet access...) Lack of specific software (programs) for the teaching and correct language Lack of technical training in ICT management Lack of models or examples of curricular integration in this discipline Lack of time and difficulty in organizing the curriculum The pedagogical benefits are not clear (researches, reports...)

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Article

The Influence of Technology on Mental Well-Being of STEM Teachers at University Level: COVID-19 as a Stressor

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Abstract: Stress can result in psychopathologies, such as anxiety or depression, when this risk factor continues in time. One major stressor was the COVID-19 pandemic, which triggered considerable emotional distress and mental health issues among different workers, including teachers, with another stressor: technology and online education. A mixed-method approach is presented in this research, combining a cross-sectional study of university teachers from Ecuador and Spain with a medium of twenty years of working experience (N = 55) and a bibliometric analysis carried out in three databases (161 documents). The levels of anxiety and depression, and therefore the risk of developing them as mental disorders, were high. The lack of training ($p < 0.01$), time ($p < 0.05$), or research regarding the use of technology in education ($p < 0.01$) and stress caused by COVID-19 ($p < 0.001$) were linked to frequency. The most relevant observational study obtained through the bibliometric analysis (138 citations and over 65% of methodological quality) indicated that previous training and behavioral factors are key in the stress related to technology. The combination of the results indicated that mental health in STEM teachers at university is related to diverse factors, from training to the family and working balance.

Keywords: mental health; mixed-method; STEM teachers; university; COVID-19

2. Introduction

The occupational safety and health (OSH) standards indicated the obligation of any employer to maintain both the physical and psychological well-being of the employees in the working environment [1,2]. Despite the guidelines and the legal framework, the adaptation of the working environment, especially to maintain mental health, continues to be limited or inadequate [3,4]. The problem resides in the fact that psychological and psychiatric disorders of workers impact their physiological and biological health as well as the productivity of the corporate, company, or employer [5,6]. In this sense, different authors have indicated how the prevention or treatment of mental disorders and their psychological component [7], including the adequation of the working place, equally contributes to workers' well-being [8,9].

One significant aspect that favors alterations of the mental health area is stress [5]. Stress, a physiological response to internal or external factors or stressors, provokes the triggering of the sympathetic system, causing the reaction of the autonomous nervous system and the hypothalamic-pituitary-adrenal (HPA) gland axis [10,11]. This stimulation results in neurologic, endocrinologic, psychological, cognitive, and behavioral reactions, from increase of blood pressure, heart rate, blood glucose, vigilance or alertness, to containment of inflammatory or immune response [12,13]. The concerning issue is when this stimulation of the nervous system and HPA axis continues for medium and long periods, resulting in major health issues, such as infertility [14]. Although most stressors, both interior and exterior, tend to have short duration effect [15], the continuous stress exposition may be derivate in psychopathologies depending on the individual responses, therefore, causing anxiety [16], depression [17], and other mental health disorders [18].

One major exterior stressor was the COVID-19 pandemic [19–21], which triggered considerable emotional distress and mental health issues among different workers [22,23]. Most researchers have analyzed the impact of this pandemic, focusing on the healthcare workers [24–26], since they were the more exposed and had a higher risk of accidents. Despite the mental impact that occurred in the hospitals and healthcare sector, other employees also suffered from emotional and mental distress caused by the lockdown and the requirements of the working. Among the numerous areas impacted by COVID19 [27], education took a toll since the educational centers and teachers had to change from face-to-face education to online teaching [28–30], without the proper tools or training in most cases.

In this sense, several studies indicated how stress or anxiety levels were higher than expected among teachers in the different educational levels [17,31,32]. This prevalence was represented as emotional tiredness, fatigue, headaches, sleep problems, eating or appetite alterations or disorders, irritability, exasperation, depressing feelings, or inability to focus [17,31,32]. One factor contributing to these emotional and mental issues is the

technology or the information and communication technologies (ICTs), an external stressor [33]. The technology as a stressor is called technostress, described as a significant factor contributing to stress even before the pandemic [34]. In this case, minor studies have been carried out to determine the effect of technostress [35,36]. Only a recent study has pointed out how technostress and the burnout syndrome are reduced when the teachers have higher levels of technological pedagogical knowledge, being explained as 70% of the current prevalence [37]. Therefore, the factor that seems to increase the levels of anxiety, stress, and depression [17,33] among teachers appears to be the technology [37]. One study indicated how teachers from science, technology, engineering, and mathematics (STEM) backgrounds, such as engineering degrees, had less risk since their ICTs' skills or training protect them against the technostress [38]. A Turkish study (2020) indicated how technological knowledge, which is higher among STEM teachers, decreases the probability of developing emotional problems and technostress [39]. Despite these results and relevance regarding technology and mental health, researchers continue not studying the teachers' perception regarding technology, such as frequency of use or skills, as factors that may contribute to the stress or decrease the effect of technostress [36,37].

Another factor contributing to emotional or mental health was the lack of resources or training, but few studies in higher education have indicated the teachers' perspective regarding these difficulties [40,41]. The issue is whether these teachers' mental risks could be managed through ICTs training and the availability of resources.

2. STEM Education, STEM Teachers, and Mental

Health Despite being present for the last 30 years and being highly discussed, STEM education has been recently conceptualized and defined [42]. One of the complete definitions is the one given by Moore et al. [43] that defines it as "the teaching and learning of the content and practices of disciplinary knowledge, which include science and/or mathematics through the integration of engineering and engineering design practices of relevant technologies".

This definition in combination with other authors [44,45] reflect how STEM education incorporates not only the teaching of scientific or mathematical concepts but also the engineering use and design of technology as well as the skills needed to adequately use such tools [42]. Despite this, Bybee [46] indicates that perhaps this definition depends on the individual's context and needs, being modifiable, subject to the current moment. Besides, a STEM teacher, which can be defined as an educator with a curriculum based on the four disciplines (science, technology, engineering, and mathematics) and understanding of the STEM education, should use technology and know the engineering design that provide the base for the ICTs [42]. Therefore, a STEM

teacher is not only someone that instructs different scientific knowledge and skills, but rather has previous training and reasonable comprehension of the dynamics and bases of ICTs in education [47]. Usually, STEM teachers are more commonly framed in elementary or high school education, although the definition of this type of teacher is also applicable to the higher education institutions [48]. Nevertheless, there is no precise description for STEM teachers, much less a conceptualization of STEM teachers at university level [49].

Despite the lack of conceptualization of the figure, several studies have analyzed the perception and aptitudes of pre-service STEM teachers, mainly in the primary and secondary educational level [42,44,46,50] that indicated a need for training. Only one article [51] focused on in-service teachers, both STEM and non-STEM, which showed a concern about the engineering course within STEM disciplines since many STEM and non-STEM teachers had low levels of engineering bases, which contradicts the definition of STEM education [43]. Berisha and Vula [50] indicated in their study how pre-service teachers that received a course in this methodology perceived a lack of collaboration or unwillingness as challenges to implement this education. In this sense, teachers with a STEM background usually avoid including new educational methodologies, such as flip classrooms, gamification, or blended learning, since they tend to carry out the same educational methodologies that they were taught [51]. One reason for the reticence of teachers is that STEM teaching has, as a purpose, deep understanding of science and/or mathematics content, engagement of students through the educational pedagogics and ICTs, and improvement of communication skills and teamwork among students [52]. These teachers' expectations could provoke high levels of stress and other psychological issues [51]. Despite this risk, most studies have indicated that STEM teachers tend to have fewer mental issues, possibly for the training received during the early stages of their career [53]. The previous data showed that STEM teachers in mainly primary and secondary educational levels had lower levels of anxiety and other emotional issues related to their ICTs' knowledge, skills, and training [36,38,39]. These studies also focused on mixed approaches, including surveys and interviews, to further understand the relationship between these workers' perception and their mental health, who seemed to be more prepared against the stress related to ICTs [37–39].

Nevertheless, these teachers' skills, knowledge, or ability might not have had to be at the highest level when the pandemic struck the world [29,30,41]. The pandemic of COVID19 obliged to switch the educational process from face-to-face to online, putting further pressure and stressor on the teachers at any educational level [17,38]. Several studies have analyzed psychological impact, such as stress or anxiety, among teachers from high schools, with relevance to Latin America or Spain [17,54,55]. Little studies have focused on

the in-service teachers at the university level and their psychological status [18,56]. Other researchers have analyzed the university teachers' skills or resources available at the beginning of the pandemic [57,58], including two intercontinental researches focusing on Ecuador and Spain whose primordial population were students [59,60]. In these two articles [59,60] carried out by the same authors, the results indicated how students and university teachers indicated that they had faced difficulties, being extremely significant to the lack of training or the lack of teachers' digital skills. This comparison between the two countries is achievable since the educational systems, laws, and structure are similar [61],showing that the deficiency of resources or training for the switch to online education seemed to be present at the same percentage across countries [57,58].

Another aspect that has been highlighted in previous studies is the importance of reviewing the scientific content, especially in education during the pandemic [62]. This fact was already pointed out by Milner-Bolotin [63], who emphasized the relevance of review and accessible evidence regarding STEM teaching and the education or training that these employees had. Nonetheless, no study has reviewed neither analyzed any intercontinental differences, mainly Ecuador and Spain, regarding the emotional impact of in-service university teachers with high experience in STEM education (e.g., university teachers in engineering courses), regarding their perception about skills or absence of resources and being framed in the STEM education. In accordance with the absence of information and the significance of reviewing scientific content [63], the current research has implemented a mixed-method combining the study and recruiting of new data and bibliographic analysis of current research focusing on this topic in order to obtain a better comprehension of the results.

Therefore, and based on the lack of evidence regarding the teachers' psychological impact of COVID-19 at the university level, the role of STEM and their training and no current analysis of previous studies, the current research had as objectives:

O1. To analyze the level of anxiety and depression among teachers with high expertise in STEM education, and therefore, high level of ICTs' skills and engineering understanding.

O2. To determine the associations between the level of anxiety and depression, and their risk related to the difficulties that this population may perceive, such as the deficiency of training, resources or the stress caused by COVID-19.

O3. To review the current knowledge available about the ICTs, university, and their mental health and comprehend the results obtained in the observational study.

O4. To examine the importance of STEM education and its training as a protective factor to mental problems among university teachers.

3. Materials and Methods

3.1. Sample, Data Collection, and Survey

A transverse descriptive investigation was implemented through a target population of teachers with a median of twenty years of working experience in different institutions from Spain and Ecuador (Table 1). The selection of the sample and institutions was founded on the fact that teachers with a STEM background seemed to have more ICTs' skills, and therefore, have lower risk of mental health issues related to the technostress [64,65]. The survey was distributed from September to October 2020 after the first lockdown in both countries. This non-probabilistic sampling had, as selection criteria, the accessibility and the relevance according to international ranking since the positions of institutions in this ranking would imply higher levels of ICTs' skills and accessibility of resources. These criteria delimited to universities from Spain and Ecuador with an interest for Engineering courses, being selected two universities with higher rankings in STEM education (Madrid and Valencia), two in the middle and two in the lower section of the ranking (Cordoba and Ecuador) [66]. The invitation to participate was sent to different teachers from STEM faculties, mainly Engineering, since the level of ICTs' skills and engineering knowledge should be the highest, and after receiving confirmation and willingness to participate, the survey link was sent. Additionally, these participants were asked to distribute the survey among other colleges working in the same school, providing a randomness to the sample. The sample of teachers that accessed the survey was 173, however, only 90 teachers started the survey (Table 1). Out of these 90 teachers, two indicated "No" to give their consent to participate and 20 only filled two questions. The remaining 70 teachers completed at least a minimum of 5 questions, with the questionnaire completely filled by 55 teachers, most of them from Ecuador. The teachers who accepted to contribute were from the top, medium, and bottom of the ranking; three were from Spain and one from Ecuador.

Table 1. Initial data of the procedure and the study population.

Procedure	*N*	Responses	Completed the Surveys	Frequencies of Response
Sent out survey email invitation to STEM departments (i.e., engineering or physics) from the Engineering School	24 email survey invitations sent, which were resent by the teachers to other colleges	Three centers for Spain (Valencia, Seville, and Cordoba) One center for Ecuador	-	60% of Spanish 100% of Ecuadorian centers
Average response of the surveys	173 teachers accessed the surveys	45 in Spain 45 in Ecuadorian center	18/45 completed the survey in Spain 37/45 completed the survey in Ecuador	40% in Spain 82.2% in Ecuador

Variables	Teachers that Completed the Survey (*N* = 55)	
	N	Frequencies
Working experience	19 with less than 10 years 15 with an experience between 10 to 20 11 with an experience between 20 to 30 10 with more than 30 years	34.5% with less than 10 years 27.3% with an experience between 10 to 20 20.0% with an experience between 20 to 30 18.2% with more than 30 years
Teaching level	42 undergraduate 13 postgraduate	76.4% undergraduate 23.6% postgraduate
ICTs' skills	11 indicted enough 32 indicated numerous 12 indicated outstanding	20% indicted enough 58.2% indicated numerous 21.8% indicated outstanding

Note: The estimation of the sample was based on previous intercontinental researchers [59], with 6% of anxiety related to new information and communication technologies (ICTs) [67] and having an expected rate of response set at 5% per center [68]

This study was completed through an original and specific online survey, which included informed consent and the study's objective. The survey included 11 items focused on ICTs and education (ICTs' skills, frequency of using ICTs, opinion regarding lack of ICTs), the impact of COVID-19 on their level of stress ("Do you consider that COVID-19 has increased your stress level?"), and the anxiety and risk of depression scales. The online survey was distributed via QuestionPro (Survey Analytics LLC, San Francisco, CA, USA). The first page of the survey was formed by the information about the research, its purpose, ethical code, confidentiality, and anonymization. After the agreement to partake in the research, the participants were redirected to the items of the questionnaire; it was possible to unmark or indicate 'unknown' for each question. The survey included teachers' opinions about ICTs (frequency of using ICTs, relevance of the ICTs and role in education, ICTs' skills, and obstacles of using ICTs), whose validity, reliability, and consistency was acceptable [69]; the next section included the perception of COVID-19 in stress levels (with a response of Yes, No or Maybe), a Linkert scale (from 1 = No stress to 5 = Maximum stress) of stress caused by the imposition of ICTs, the technical issues suffered and balance between family and work, and finally, the Rosenberg subscales of risk to have anxiety and depression, with nine items each and dichotomic responses [70]. This research followed the Declaration of Helsinki and the Data Protection Law 3/2018 following these codes and receiving approval (Ref. 4258), being updated in 2021 (Ref. 4950).

For this study, the qualitative variables, such as country or teachers'

perspectives regarding ICTs, were calculated via frequencies (absolute and relative) and the median. For the quantitative variables, which were the exact level obtained in Rosenberg subscales of risk to have anxiety and depression [70], the mean, standard deviation, and 95% confidence intervals (CI) were used. Additionally, the breakpoint established for the subscales were used as a positive diagnostic of risk for anxiety and depression (four or more for the anxiety and two or more for anxiety) were analyzed to determine associations [70]. The Kolmogorov–Smirnov test was applied and indicated that the data did not follow the normality ($p < 0.001$). The chi-square test, Mann–Whitney U test, Kruskal–Wallis, and Spearman's correlation tests were used.

3.2. Bibliographic Search

Three simultaneous searches using the Scopus, Web of Science (WOS), and Medline via PubMed databases were performed using the PICO (Population, Intervention, Comparison, and Outcomes) structure. The bibliographic search was carried out using the Medical Subject Heading (MeSH) terms, which were previously selected in accordance with the research's purposes (O3 and O4) (Table 2). Additionally, the keyword "teachers" or "academic" were incorporated in the search to gather more publications.

Table 2. Description of MeSH terms.

Medical Subject Heading (MeSH) Terms	Description
Mental Health	"Emotional, psychological, and social well-being of an individual or group"
Mental Disorders	"Psychiatric illness or diseases manifested by breakdowns in the adaptational process expressed primarily as abnormalities of thought, feeling, and behavior producing either distress or impairment of function"
Anxiety Disorders	"Persistent and disabling anxiety"
Mood Disorders	"Those disorders that have a disturbance in mood as their predominant feature"
Depressive Disorder	"An affective disorder manifested by either a dysphoric mood or loss of interest or pleasure in usual activities. The mood disturbance is prominent and relatively persistent"
Anxiety	"Feelings or emotions of dread, apprehension, and impending disaster but not disabling as with anxiety disorders"
Stress Disorders, Traumatic	"Anxiety disorders manifested by the development of characteristic symptoms following a psychologically traumatic event that is outside the normal range of usual human experience. Symptoms include re-experiencing the traumatic event, increased arousal, and numbing of responsiveness to or reduced involvement with the external world. Traumatic stress disorders can be further classified by the time of onset and the duration of these symptoms"
Universities	"Educational institutions providing facilities for teaching and research and authorized to grant academic degrees"
Schools	"Educational institutions"
Teaching	"A formal and organized process of transmitting knowledge to a person or group"

Medical Subject Heading (MeSH) Terms	Description
Faculty	"Teaching and administrative staff having academic rank in a post-secondary educational institution"
Technology	"The application of scientific knowledge to practical purposes in any field. It includes methods, techniques, and instrumentation"
Educational Technology	"Systematic identification, development, organization, or utilization of educational resources and the management of these processes. It is occasionally used also in a more limited sense to describe the use of equipment-oriented techniques or audiovisual aids in educational settings"
Computer User Training	"Process of teaching a person to interact and communicate with a computer"
Models, Educational	"Theoretical models which propose methods of learning or teaching as a basis or adjunct to changes in attitude or behavior. These educational interventions are usually applied in the fields of health and patient education but are not restricted to patient care"

The bibliometric analysis was implemented in July 2021 using the research accordingly to each database. The Boolean operators chosen were "OR" and "AND", and the fields used to identify the relevance were "title", "abstract", and "keywords". For Scopus, the research included the use of abstract, title, and keywords ((TITLE-ABS-KEY ("mental health") OR TITLE-ABS-KEY ("mental disorders") OR TITLE-ABS-KEY ("Anxiety Disorders") OR TITLE-ABS-KEY ("Mood Disorders") OR TITLE-ABS-KEY ("Depressive Disorder") OR TITLE-ABS-KEY ("Anxiety") OR TITLE-ABS-KEY ("stress disorders, traumatic")) AND (TITLE-ABS-KEY ("universities") OR TITLE-ABS-KEY ("schools") OR TITLE-ABS-KEY ("teaching")) AND (TITLE-ABS-KEY ("faculty") OR TITLE-ABS-KEY ("teachers") OR TITLE-ABS-KEY ("academics")) AND (TITLE-ABS-KEY ("technology") OR TITLE-ABSKEY ("Educational Technology") OR TITLE-ABS-KEY ("Computer User Training") OR TITLE-ABS-KEY ("Models, Educational") OR TITLE-ABS-KEY ("ICTs")). In the case of WOS, the research was implemented focusing on the topic as the descriptor obtaining the following research strategy: TS = (("mental health" OR "mental disorders" OR "Anxiety Disorders" OR "Mood Disorders" OR "Depressive Disorder" OR "Anxiety" OR "stress disorders, traumatic") AND ("universities" OR "schools" OR "teaching") AND ("faculty" OR "teachers" OR "academics") AND ("technology" OR "Educational Technology" OR "Computer User Training" OR "Models, Educational" OR "ICTs")). Finally, the Medline research was based on the use of the MeSH terms and other terms obtaining the following strategy: ((Mental health[MeSH Terms]) OR (mental disorders[MeSH Terms]) OR (anxiety disorders[MeSH Terms])) OR (mood disorders[MeSH Terms]) OR (depressive disorder[MeSH terms]) OR (anxiety[MeSH Terms]) OR (stress disorders, traumatic[MeSH Terms]) AND (universities[MeSH Terms]) OR (schools[MeSH Terms]) OR teaching[MeSH Terms])) AND ((faculty[MeSH Terms])) OR (teachers[Other Term]) OR (academic[Other Term])) AND ((technology[MeSH Terms]) OR (educational technology[MeSH Terms]) OR (Computer User

Training[MeSH Terms]) OR (Models, Educational[MeSH Terms]) OR (ICTs[Other Term])). The exclusion criteria were publications whose population were students, teachers from secondary or primary level, studies over 20 years, studies that did not include the technology, or whose topic concentrates on patients. Selected studies were those related to teachers from the university level's use of ICTs and the influence of mental health. Before 1 July 2021, there were identified 2776 documents published, that addressed the topic of teachers, mental health, and technology. During the screening, 2541 studies were eliminated from the study since in their titles, abstracts, and/or keywords referred to different populations (such as teachers from high schools), intervention (that did not include any type of technology) or outcomes (related to the mental health or emotional distress). The following stage, further articles were excluded according to content of the text and timeframe, articles whose population were teachers of secondary level or the lack of inclusion of ICTs. In this phase, 59 documents were eliminated, also excluding 15 papers that were duplicated (Figure 1).

The statistic package called SPSS version 24 (IBM Corporation, Armonk, NY, USA), VOSviewer version 1.6.15 (Ness Jan van Eck, The Netherlands), and Excel version 17 (Microsoft Corporation, Redmond, Washington, USA) were implemented to study the data obtained after the screening of the search (Figure 1). Additionally, with the information provided by the databases, the Clarivate Journal Citation Report was used to define which journal was indexed, the Journal Impact Factor of the year of publication, the quartile of the journal, and the JIF percentile. Relative frequencies and medium were implemented for qualitative variables, i.e., country, journal, or year of publication. Based on the normalization test ($p < 0.001$), Mann–Whitney, chi-square U, Kruskal–Wallis tests, and Spearmen's correlation were applied for the quantitative variables of the 161 documents (Appendix A Table A1), Additionally, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Checklist [71] was applied for the analysis of the quality of the methodology of the top five observational studies in the area (Appendix A Table A2).

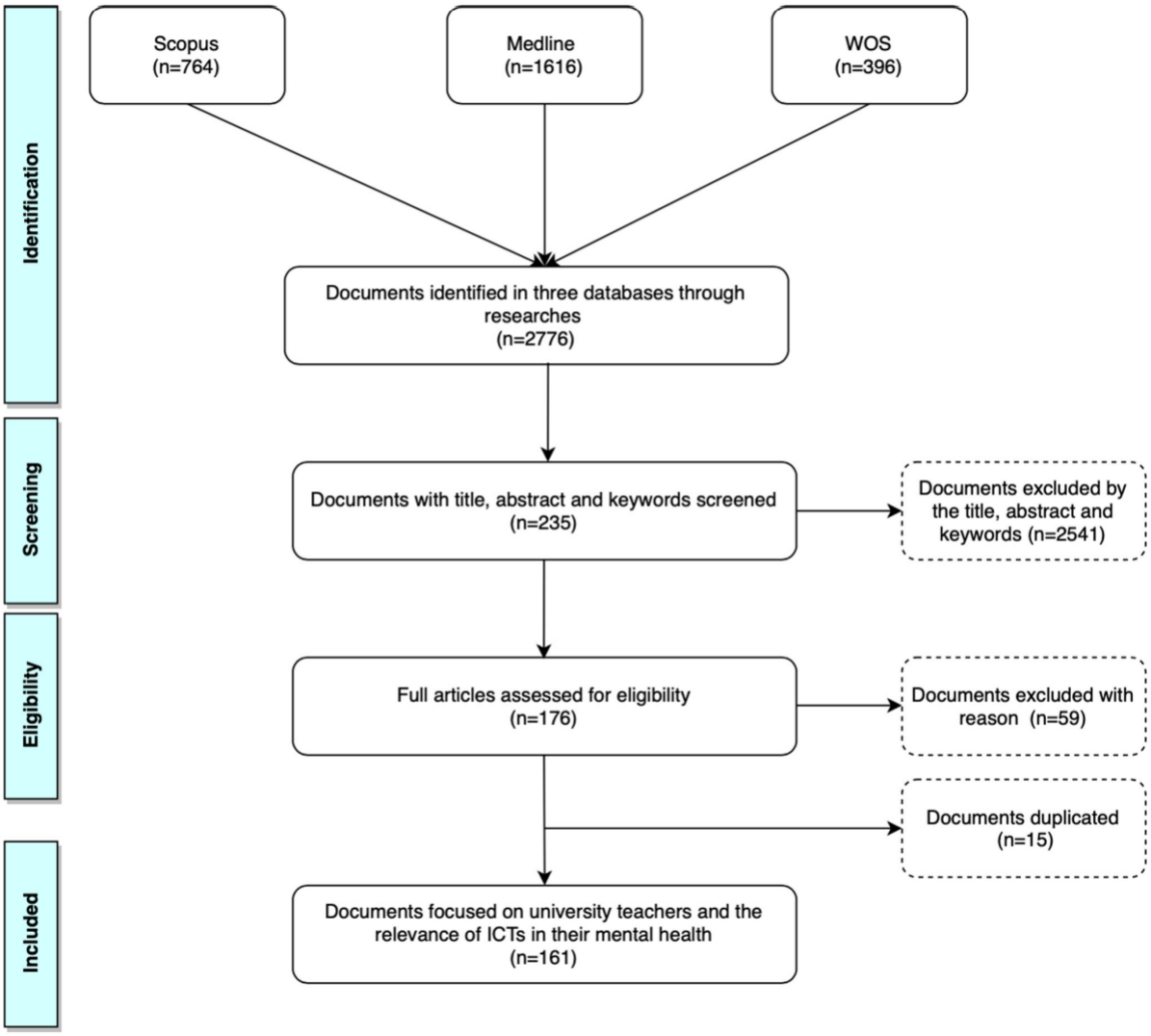


Figure 1. Flow diagram followed for collecting data using the stages of identification, screening, eligibility, and inclusion

4. Results

4.1. STEM Teachers at University Level

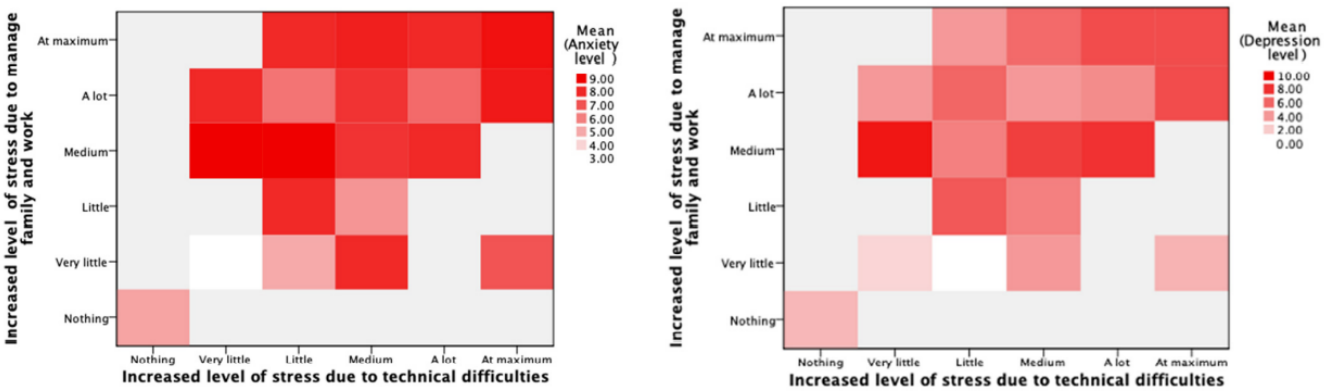
The observational study's initial analysis showed that 32.7% of the participants came from Spanish high education institutions, while 67.3% worked in Ecuador; 76.4% of the university teachers taught undergraduate students, with a median of 10 years of experience (34.5% had less than ten years, and 27.3% had between 10 to 20 years of experience). The mean level of anxiety was set at 6.84 ± 2.54 (95% CI 6.15–7.24); meanwhile, the mean depression level was 4.91 ± 2.89 with a 95% IC 4.13–5.69. The analysis of the anxiety and depression

levels indicated that for the country, working experience, and teaching at different levels (Table 3) showed no significant differences except for the case of the depression level, which varied per country ($p = 0.009$). The mean of the depression level was 5.5 ± 3.24 (95% CI 3.88–5.53) among Spanish teachers in contrast with the 4.6 ± 2.71 (95% CI 3.71–7.11) of Ecuadorian university teachers. Nevertheless, the correlations for the level of anxiety and depression were not linked to any of the previous variables ($p > 0.05$).

Table 3. Differences and correlations of the variables and the anxiety and depression levels.

Variables	Anxiety Level		Depression Level	
	Differences	Correlation (*p*-Value)	Differences	Correlation (*p*-Value)
Country	0.38	−0.70 (0.61)	0.009	−0.17 (0.21)
Working experience	0.17	−0.12 (0.93)	0.59	−0.043 (0.76)
Teaching at different levels	0.77	0.59 (0.66)	0.41	−0.15 (0.41)
Role of the ICTs in the education	0.67	0.45 (0.001)	0.045	0.29 (0.033)
Availability of computer	0.016	−0.07 (0.63)	0.027	0.028 (0.84)
Availability of internet	0.031	−0.29 (0.027)	0.45	−0.23 (0.096)
Frequency of using ICTs (virtual environments)	0.037	0.16 (0.25)	0.11	−0.26 (0.053)
Lack of resources	0.013	0.48 (0.001)	0.08	0.29 (0.033)
Lack of software	0.012	0.37 (0.005)	0.039	0.25 (0.071)
Lack of training	0.003	0.49 (<0.001)	0.43	0.31 (0.025)
Lack of models	<0.001	0.55 (<0.001)	0.025	0.38 (0.004)
Lack of time	0.002	0.49 (<0.001)	0.022	0.29 (0.033)
Lack of evidence	0.01	0.35 (0.01)	0.021	0.25 (0.071)

The anxiety and depression levels of the teachers were linked to the perception regarding the ICTs, the availability of resources, lacking resources as an obstacle, and COVID-19 ($p < 0.05$) (Table 3). Additionally, COVID-19 as a stressor (presented in 78.18%) showed significance regarding the level of anxiety ($p = 0.022$) and depression ($p = 0.006$). Another factor that showed relevance for the levels of anxiety and depression was the balance between family and work ($p = 0.01$). The correlations (Table 3) indicated that the level of anxiety increased by the inability of having internet ($p = 0.027$), the lack of resources ($p = 0.001$), training ($p < 0.001$), models ($p < 0.001$), time ($p < 0.001$), research that indicates the benefits of the use of ICTs ($p = 0.01$), the stress caused by COVID-19 ($\rho = 0.31$; $p = 0.021$), stress related to the need to use ICTs ($\rho = 0.42$; $p = 0.001$), the technical issues ($\rho = 0.39$; $p = 0.003$), and the balance between the family and work ($\rho = 0.42$; $p = 0.001$) (Figure 2). Meanwhile, the depression level was linked to having less ICTs' skills ($\rho = -0.39$; $p = 0.011$), the lack of resources ($p = 0.033$), training ($p = 0.025$), models ($p = 0.004$), time ($p = 0.033$) (Table 2), the stress caused by COVID-19 ($\rho = 0.38$; $p = 0.005$), stress related to the need to use ICTs ($\rho = 0.43$; $p = 0.001$), the technical issues ($\rho = 0.43$; $p = 0.001$), and the balance between the family and work ($\rho = 0.42$; $p = 0.001$) (Figure 2).



(a) (b)

Figure 2. Comparison of the correlations between the technical issues and the balance between the family and work related to the anxiety (a) and depression levels (b) through a heat map.

Based on the levels of anxiety and depression, the risk of developing each was analyzed. The risk of developing anxiety among the teachers was 85.5%, being presented as similar frequency among Spanish (83.3%) and Ecuadorian (86.5%) ($p > 0.05$). The risk of developing anxiety showed significant differences in the role of ICTs in education and lack of ICTs (resources, software, training, models, time, and research about the benefits of ICTs) ($p < 0.05$) (Table 4). Additionally, COVID-19 as a stressor showed a significant difference between the teachers with a risk of anxiety (82.98%) ($X2 = 8.03$; $p = 0.005$). Meanwhile, the risk of depression was related to COVID-19 as a stressor ($X2 = 4.39$; $p = 0.037$), the balance between family and work ($X2 = 16.3$; $p = 0.006$), availability of computers and internet, the role of the ICTs in education, lack of models, and time ($p < 0.05$) (Table 4).

Table 4. Variables that indicated significant differences for the risk of anxiety and depression.

Variables	Answers	Risk of Anxiety		*p*-Value	Risk of Depression		*p*-Value
		Yes	No		Yes	No	
Availability of computer	Rather not say	0 (0%)	0 (0%)	0.081	0 (0%)	0 (0%)	0.004
	Nothing	2 (4.26%)	2 (25.00%)		0 (0.0%)	4 (22.22%)	
	Little	5 (10.64%)	0 (0.0%)		5 (13.51%)	0 (0.0%)	
	Enough	10 (21.28%)	0 (0.0%)		9 (24.32%)	1 (5.56%)	
	A lot	30 (63.83%)	6 (75.00%)		23 (62.16%)	6 (72.22%)	
Availability of internet	Rather not say	0 (0.0%)	0 (0.0%)	0.24	0 (0.0%)	0 (0.0%)	0.048
	Nothing	0 (0.0%)	0 (0.0%)		0 (0.0%)	0 (0.0%)	
	Little	0 (0.0%)	0 (0.0%)		0 (0.0%)	0 (0.0%)	
	Enough	8 (15%)	0 (0.0%)		7 (18.92%)	0 (0.0%)	
	A lot	40 (85%)	8 (100%)		30 (81.08%)	8 (100%)	
Role of the ICTs in the education	No	41 (87.23%)	6 (75.00%)	0.002	31 (83.78%)	16 (88.89%)	0.029
	Maybe	0 (0.0%)	2 (25.00%)		0 (0.0%)	2 (11.11%)	
	Yes	6 (12.77%)	0 (0.0%)		6 (16.22%)	0 (0.0%)	
Lack of resources	No obstacle	5 (10.64%)	4 (50.00%)	0.042	4 (10.81%)	5 (27.78%)	0.152
	Less important	2 (4.26%)	0 (0.0%)		2 (5.41%)	0 (0.0%)	
	Important in some cases	12 (25.53%)	1 (12.50%)		7 (18.92%)	6 (33.33%)	
	Considerably important	6 (12.77%)	2 (25.00%)		5 (13.51%)	3 (16.67%)	
	Highly important	22 (46.81%)	1 (12.50%)		19 (51.35%)	4 (22.22%)	
Lack of software	No obstacle	2 (4.26%)	4 (50.0%)	0.003	1 (2.70%)	5 (27.78%)	0.056
	Less important	3 (6.38%)	0 (0.0%)		2 (5.41%)	1 (5.56%)	
	Important in some cases	13 (27.66%)	0 (0.0%)		10 (27.03%)	3 (16.67%)	
	Considerably important	11 (23.40%)	2 (25.0%)		8 (21.62%)	5 (27.78%)	
	Highly important	1838.30%)	2 (25.0%)		16 (43.24%)	4 (22.22%)	
Lack of training	No obstacle	1 (2.1%)	4 (50.0%)	<0.0001	1 (2.70%)	4 (22.22%	0.1
	Less important	3 (6.4%)	1 (12.5%)		3 (8.11%)	1 (5.56%)	
	Important in some cases	12 (25.5%)	2 (25.0%)		8 (21.62%)	6 (33.33%)	
	Considerably important	10 (21.3%)	1 (12.5%)		8 (21.62%)	3 (16.67%)	
	Highly important	21 (44.7%)	0 (0.0%)		17 (45.95%)	4 (22.22%)	
Lack of models	No obstacle	1 (2.13%)	4 (50.00%)	<0.0001	1 (2.70%)	4 (22.22%)	0.021
	Less important	2 (4.26%)	0 (0.0%)		2 (5.41%)	0 (0.0%)	
	Important in some cases	10 (21.28%)	3 (37.50%)		7 (18.92%)	6 (33.33%)	
	Considerably important	15 (31.91%)	1 (12.50%)		10 (27.03%)	6 (33.33%)	
	Highly important	19 (40.43%)	0 (0.0%)		17 (45.95%)	2 (11.11%)	
Lack of time	No obstacle	1 (2.13%)	4 (50.00%)	<0.001	1 (2.70%)	4 (22.22%)	0.065
	Less important	1 (2.13%)	2 (25.00%)		1 (2.70%)	2 (11.11%)	
	Important in some cases	9 (19.15%)	0 (0.0%)		7 (18.92%)	2 (11.11%)	
	Considerably important	16 (34.04%)	1 (12.50%)		14 (37.84%)	3 (16.67%)	
	Highly important	20 (42.55%)	1 (12.50%)		14 (37.84%)	7 (38.89%)	
Lack of evidence	No obstacle	3 (6.38%)	5 (62.50%)	0.001	2 (5.41%)	6 (75.00%)	0.1
	Less important	3 (6.38%)	1 (12.50%)		3 (8.11%)	1 (12.50%)	
	Important in some cases	17 (36.17%)	2 (25.00%)		14 (37.84%)	5 (62.50%)	
	Considerably important	12 (25.53%)	0 (0.0%)		9 (24.32%)	3 (37.50%)	
	Highly important	12 (25.53%)	0 (0.0%)		9 (24.32%)	3 (37.50%)	

Furthermore, the correlations were analyzed for each variable and the risk of anxiety and depression (Table 4). The anxiety risk was linked to the frequency of using virtual environments ($\rho = 0.30$; $p = 0.026$), the lack of resources ($p = 0.032$), training ($p < 0.001$), models ($p < 0.001$), time ($p = 0.001$), and research about the benefits of using ICTs in the education ($p < 0.001$) (Table 4). Additionally, COVID-19 ($p = 0.037$), need to use ICTs ($p = 0.005$), technical issues ($p = 0.005$), and the balance between family and work ($p = 0.006$) were linked to having a higher risk of anxiety (Table 5). Besides, risk of having depression (Table 4) was linked to the unavailability of internet ($\rho = -0.67$; $p = 0.049$), less ICTs' skills ($\rho = -0.34$; $p = 0.011$), the lack of resources ($p = 0.038$), training ($p = 0.025$), and models ($p = 0.006$). This risk was associated with COVID-19 as a stressor ($p = 0.004$), need to use ICTs ($p = 0.001$), technical issues ($p = 0.007$), and the balance between family

and work (p = 0.001) were linked to having a higher risk of anxiety. Finally, the risk of anxiety and depression was connected (ρ = 0.59; p < 0.001).

Table 5. Variables that indicated significant differences for the anxiety and depression levels.

Variables	Risk of Anxiety		Risk of Depression	
	Correlation	*p*-Value	Correlation	*p*-Value
Lack of resources	0.029	0.032	0.28	0.038
Lack of software	0.21	0.13	0.26	0.053
Lack of training	0.48	<0.001	0.30	0.001
Lack of models	0.49	<0.001	0.37	0.006
Lack of time	0.43	0.001	0.15	0.27
Lack of evidence	0.49	<0.001	0.24	0.076
COVID-19 as a stressor	0.28	0.037	0.38	0.004
Imposition of ICTs as a stressor	0.37	0.005	0.43	0.001
Technical difficulties as a stressor	0.37	0.005	0.36	0.007
Balance between family and work as a stressor	0.36	0.006	0.43	0.001

Finally, a multivariant analysis based on linear regression for positive risk of anxiety among STEM teachers at university level indicated (R2 = 0.62; p = 0.016) that this risk is dependent on lack of time (p < 0.001), software (p = 0.016), and research that clarified the benefits of using ICTs (p = 0.005); this risk is codependent of the chance to developing depression (p < 0.001).

4.2. Bibliographic Search

The analysis of the bibliometric method reflected that most investigations were carried out in the United States (USA, with 39 documents), followed by China (with 15 papers), Turkey (with 14 documents), the United Kingdom (10 articles), and other countries (Spain and Ecuador with less than five documents each) with few publications on the topic studied (Figure 3). This figure presents the nations from whom the authors have published the documents (N = 161), being more often the case of countries, such as Japan or Chile, that provided only one paper. The number of publications per year and citations showed significant differences between countries (p = 0.01), with the USA being the most influential producer of publications per year (p = 0.003), indexing most of the publications (p = 0.011) in higher quartiles (p = 0.043), and higher JCR (p = 0.048). Despite this, the frequency of publications in the latest years indicated that countries with fewer investigations have increased during the last three years (ρ = −0.87; p < 0.001).

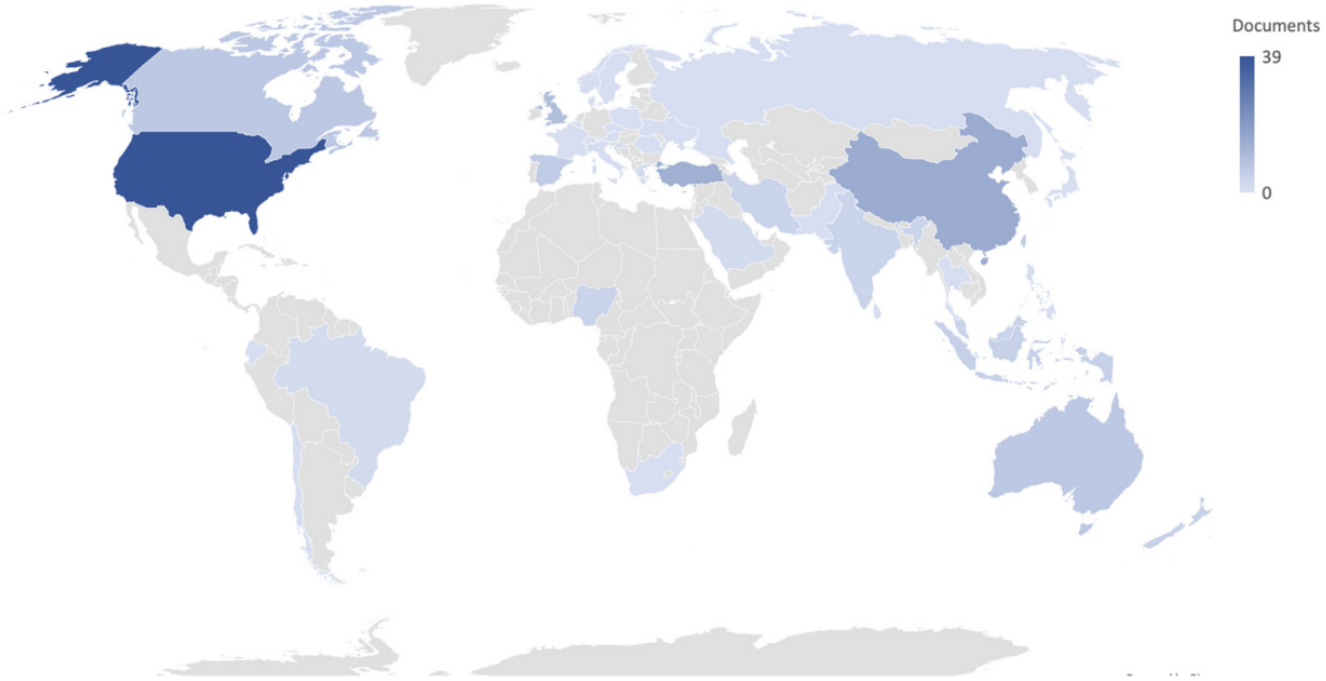


Figure 3. Distribution of the documents per country.

Nevertheless, when analyzed per continent and the year, the number of citations, journal citation report (JCR), and percentile of the journal, there were no significant differences ($p = 0.71$). There were substantial differences between continents regarding whether the journal was indexed ($X2 = 12.54$; $p = 0.014$) and the quartile ($X2 = 32.76$; $p = 0.036$). The correlations indicated how other continents such as Oceania had increased the rate of publications mainly in the last years ($p = 0.033$) but had more minor citations ($p < 0.001$), indexed journals ($p = 0.005$), and published articles in lower quartiles ($p = 0.002$) than compared to other continents, such as Europe.

Another aspect analyzed was the frequency of publications per year (Figure 4), whose highest rate was achieved in 2020, the year of the COVID-19 pandemic (29.6% of the publications made in the last 20 years). The analysis indicated that there was a significant difference between the year of publication and quartile of the article ($p < 0.001$) and the number of citations ($p < 0.001$). The correlations indicated that the latest publications had more minor citations ($\rho = -0.47$; $p < 0.001$), although the rate of publications has no significant differences ($p = 0.01$). The median of the year of publications was 2018 ($p = 0.05$); from this year, as a break point, the number of citations amplified faster ($p = 0.032$). This change (Figure 3) had similarities with the year 2015 that had 10 documents, although there was a decrease of six papers from 2016 to 2017.

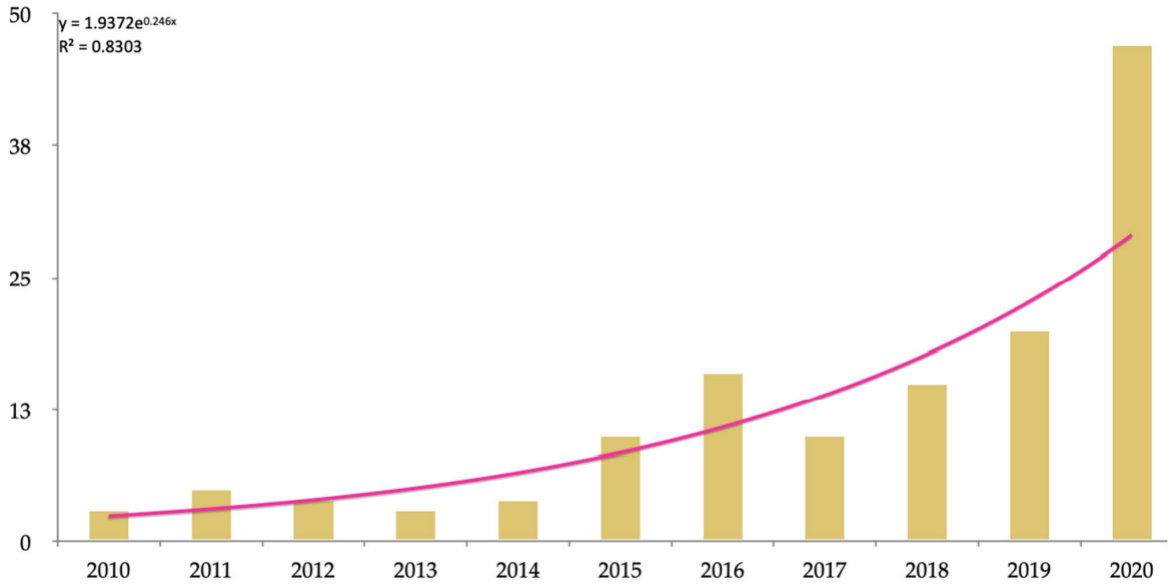


Figure 4. Distribution of the documents per year and exponential curve of publication.

The number of citations of each article diverged according to the theme ($p < 0.001$), with a mean of 8.2 citations (SD = 15.47; IC 95% = 10.63–5.77). The citations per document were linked to journal indexed, JCR of the journal of the year of publication, quartile, and percentile ($p < 0.001$). According to the citations, the top ten articles were reviews, two observational studies, two guidelines or theoretical studies, and two qualitative studies. The results indicated that this area is more common than the reviews. Based on the citations and the type of studies, the top five observational or crosssectional studies with a higher number of citations were analyzed (Table 6). The most cited article, with 138 citations and from Turkey, focused on determining the relationship between attitude to computers and anxiety for pre-teachers at the university level [72]. This article highlights the importance of computer self-efficacy and anxiety related to using such technology as predictors in the education that this teacher will provide. For teachers and education, this article clarifies how the attitude, including the technostress and ICTs' skills, are intrinsic factors related to the mental distress that university teachers may experience. The second article focused on nursing teachers and how ICTs are a risk factor for technostress [73]. The third focused on university teachers, in which it was linked the use of ICTs for the different functions and ICTs' skills, and the anxiety related to ICTs [74]. The fourth and fifth focused on how the use of ICTs in the future seems to be determined by anxiety caused by self-efficacy, behavior, or willingness [75,76]. This table displayed how more relevant observational research were published in Turkey (3/5), which is also the third country with a higher number of articles which focused on the topic, analyzed through the bibliometric analysis. Additionally, it is reflected in the top articles the existing link between an individual's skills and perception regarding ICTs and the risk of technostress; furthermore, the fourth most cited article

showed how teachers whose work is related to STEM education have lower levels of anxiety or stress related to ICTs. Besides, the quality of the methodology was analyzed (Table 5), indicating that despite having more minor citations, the second most cited article [73] had over 70% in the quality of the methodology, followed by the first article with a higher number of citations [72]. The third article with the most methodological quality was published in 2016 and had the third-ranking number of citations [74]. The remaining papers with fewer citations, and more recently, had less than 50% of methodological quality. These results indicate that the number of citations and methodological quality are critical factors in the relevance of the research published. The analysis of index keywords of each document, based on a minimum of two nodes, showed seven clusters as the most concurrency topics (Figure 5).

The issues identified seven groups (Table 7) (formed by 224 keywords indicated with 4819 links and a total of 7350 ties). The first and foremost cluster (representing 30.49% and being in red) focused on educational technology, STEM education with great emphasis on students, and teachers' self-efficacy (presenting 17.56% of co-occurrence among the keywords). This red cluster represented one of the main sub-topics based on the technology, teaching, and students focusing on STEM. The next sub-topic (green), conformed by 44 keywords (19.73%), has a central theme regarding the educational model in nursing education and the relevance of the management and organization for the psychological impact. In higher educational institutions, the third cluster (in blue), which represented 16.59% of keywords, focused on psychological issues, especially anxiety. The fourth cluster, in yellow, with the exact representation as to the third, represented the sub-topic of mental health in the health faculty, specifically the medical education, focusing on the distance education caused by the coronavirus and the psychological adaptation. The following cluster (in purple), with 20 keywords and an occurrence of 8.97%, concentrated on mental health in the health faculty and its relationship with practical education in hospitals. The sixth cluster, formed by 8.52% of the keywords and represented in pink, focused on mental stress and technology. The last cluster (orange) was created by seven keywords and presented 3.14% of weight from the seven clusters and was centered on sciences, self-concept, and the psychology in the educational sector.

Table 6. The five most-cited observational articles of the bibliometric analysis.

Title	Year	Country	Sample	Variables	Results	Source	Citations	STROBE [1] Checklist
Attitudes to technology, perceived computer self-efficacy, and computer anxiety as predictors of computer-supported education [72]	2012	Turkey	Pre-service teachers at the university level (N = 471)	Sociodemographic data, studies, department, Technology Attitude Scale, Perceived Computer Self-Efficacy Scale, Computer Anxiety Scale, and The Attitude Scale toward Applying Computer Supported Education	A model created indicated the effect level of the latent variables of attitudes to technology, computer anxiety, perceived computer self-efficacy, and the attitude toward computer-supported education on each other and their ratios.	Computers & Education	138	20/32 (62.5%)
The incidence of technological stress among baccalaureate nurse educators using technology during course preparation and delivery [73]	2005	United States	Full-time nurse educators (N = 115)	Nurse educator technostress scale (NETS) and demographic characteristics	The use of technology in the classroom was a significant predictor of nurse educators' technological stress.	Journal of Nursing Education	31	25/33 (75.76%)
A study on academic staff personality and technology acceptance: The case of communication and collaboration applications [74]	2019	Romania	University teachers (N = 1816)	The use of the online communication and collaboration applications scale, The Unified Theory of Acceptance and Use of Technology Scale, Technology anxiety scale, and The Utrecht Work Engagement Scale	ICTs for teaching and researching depend on technology anxiety and self-efficacy.	Computers & Education	22	15/32 (46.87%)
Influential factors on pre-service teachers' intentions to use ICT in future lessons [75]	2016	Turkey	Pre-teachers at different educational levels and university teachers (N = 2904)	Preservice Teachers ICT Acceptance Scale was used and included: perceived usefulness, ease-of-use, and efficacy, social influence, facilitating conditions, and computer anxiety	There was an inverse correlation between anxiety and ICT integration. There was also a negative relationship between anxiety and the teachers from scientific departments or STEM backgrounds.	Computers in Human Behavior	18	19/33 (59.59%)
A model for pre-service teachers' intentions to use ICT in future lessons [76]	2017	Turkey	Pre-service university teachers (N = 199)	A design scale that included ICTs perceive usefulness, perceived ease-of-use, social influence, facilitating conditions, computer self-efficacy, attitude towards computers, anxiety, and behavioral intention	The intention of using ICTs seems to be regulated by perceived usefulness, computer self-efficacy attitude towards computers, anxiety, and behavioral intention	Interactive Learning Environments	15	13/32 (40.63%)

[1] Strengthening the Reporting of Observational Studies in Epidemiology: STROBE Checklist.

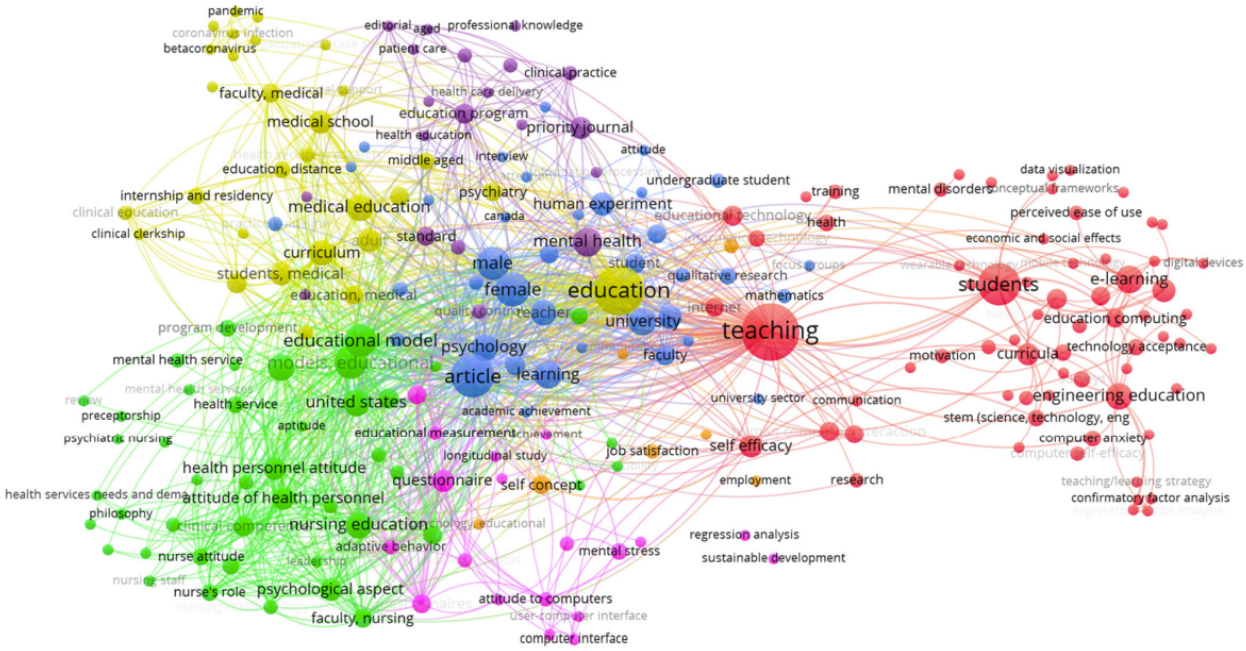


Figure 5. Co-occurrence of the repetitive terms identified per article

Table 7. *Main keywords used by the communities detected in the topic.*

Cluster	Color	Weight (%)	*Connection between* Clusters (Links per Keyword inside Each Cluster)	*Main Keywords*	*Topic*
1	Red	30.49	1638 (17.56%)	Education technology-information technology-research-STEM-students-self-efficacy	Technology in education
2	Green	19.73	2123 (22.76%)	Educational model-health personnel attitude-nursing education-organization and management-psychological aspect	Educational model in nursing and the management for the psychological impact
3	Blue	16.59	1504 (16.12%)	Faculty-learning-university-teacher-psychology-anxiety	Mental disorders in higher education institutions
4	Yellow	13.00	2171 (23.27%)	Adaptation, psychological-education-medical school-coronavirus	Distance education caused by the coronavirus and the psychological transformation in medical education
5	Purple	8.97	888 (9.52%)	Health education-educational program-mental health-university hospital-clinical practice	Education in health field, especially for clinical practices, and impact on mental health
6	Pink	8.52	740 (7.93%)	Adaptative behavior-mental stress-stress-psychological-computer assisted instruction	Mental health and technology
7	Orange	3.14	263 (2.82%)	Psychology, education-science-self-concept-job satisfaction	Sciences, self-concept, and psychology in the educational sector

5. Discussion

The mixed-method analysis has identified several important aspects. First,

from the descriptive analysis, it can be resumed in the link between anxiety levels, depression, and various impediments for online education, such as the lack of training, and the relevance of other stressors like COVID-19 or the balance between family and working, these being results independent from the country. Meanwhile, the bibliometric analysis had highlighted the lack of studies that focused on measuring the STEM teachers at the university level of mental discomfort or problems, and instead identified the STEM training that these workers have as a protective factor. Few studies have been carried out in Spain or Ecuador focusing on this relevant topic, and much less were intercontinental studies identified.

The data from the observational analysis has highlighted how STEM teachers at the university level had a high level of anxiety and depression, with the risk of developing them as a disorder elevated. The mental well-being of Spanish and Ecuadorian teachers seemed to be related to working conditions and workers' attitudes. These workers indicated that the impact of COVID-19, the imposition of using ICTs for online teaching, the technical problems, and the balance between the familiar and working environments were critical features for their stress.

There were no significance differences according to country or working experience for the anxiety and depression level; rather, these levels were associated with the perception of the STEM teachers at higher education institutions concerning diverse difficulties, such as lack of resources, training, or time. Moreover, the ICTs' skills, described as moderate-high, were not linked to anxiety or depression. This result indicated that previous skills to the pandemic seemed to have not been a protective factor against mental issues. The associations previously described may reflect how the transfer from face-to-face to online teaching was a stressor independently of the previous training in STEM education or previous ICTs' skills. These outcomes are in accordance with other researchers [77,78], whose findings showed the need for training as a vital element to prevent technostress among teachers. Furthermore, another study carried out in Ecuador specified that previous training and experience with online teaching before the pandemic was a protective factor, reducing the stress level and possibly other psychological symptoms [55]. Nevertheless, the previous studies in higher education institutions did not differentiate between STEM teachers or where they teach [55,77,78]. Another interesting finding was the impact balancing family and the working environment in the mental well-being of the participants. These results were consistent with previous studies that indicated how the inclusion of the ICTs in the living environment increases the

hostility and stress between the workers and the rest of the family members [77]. However, because of the COVID-19 restrictions, the anxiety levels of these workers continue for a long time because of the obligation to balance workload combined with the work of carrying out family care duties [79]. This imposition to balance the work demands and family duties could be one of the reasons why teachers working in the home environment indicated having higher levels of emotional issues and psychological symptoms [80]. Several studies indicated diverse psychological symptoms, mainly anxiety and stress, among teachers at different educational levels and at the university [81]. In this sense, a Chinese study indicated that posttraumatic stress disorder was around 25% among college teachers, reflecting that the incidence of mental health issues is higher in this group [23].

The current observational analysis indicated that 85% of the university teachers were at risk of developing anxiety as chronic mental health, which was also connected to depression [82,83]. The relationship between anxiety and depression, established long ago [84], was also associated with lack of time, specific software, and research that clarified the benefits of using technology. This relationship between anxiety, depression, and these obstacles could be different and be more conditional depending on the previous background or new stressors such as the impact of the pandemic. However, other studies indicated that STEM teachers had less risk of anxiety related to ICTs [72], being contradictory to the current studies since the STEM teachers also had high levels of anxiety. Other articles that analyzed the relationship between technostress and COVID-19 suggested that age or gender play a role in the anxiety linked to the technology [32,67], although these studies used only technostress and the possible effect of the family/work—the stress caused by COVID-19 or the lack of training was missing. This lack of association from previous studies has been magnified by the observational studies found in the bibliometric analysis [72–76]. The top five articles (Table 5) indicated that pre-service and in-service STEM teachers in higher education institutions had fewer mental issues and less risk. These articles [72–76] were in contract with the findings from the current observational analysis, whose findings indicated that STEM education or experience in STEM courses was not a definitive shielding factor against mental issues. In fact, the STEM teachers also suffered from psychological problems during the pandemic, which could be associated with the lack of previous experience with online learning [53]. Another aspect identified in the bibliographic analysis was the lack of studies carried out in the population selected (Spain or Ecuador), and the papers did not consider the lack of technical

support as a stressor [72–76]. Additionally, another result was that the current investigations are more commonly reviews [85,86], being also more cited. The top publications focused on recommendations [87] to prevent mental issues, qualitative approaches, and little provided current data; being less common, the perspective of STEM teachers at university level. Other prior works indicated that the highest prevalence of work-related technostress among teachers (around 10%) was related to a specific age group (women from 30 to 39 years old with children), which could be related to training, working workload, and family chores, and the field in which the education is provided [73,87]. Thus, most works focused on analyzing prevalence and its relationship with the teachers' attitudes but did not include the teachers' perspective regarding obstacles such as the lack of ICTs [72–76]. Additionally, these articles (Table 5) focused on Turkey and pre-service faculty members, not including the STEM teachers as an independent group but studying this population in combination with other educators [72–76]. Additionally, one study focused on healthcare teachers [73] showed that lectures from health sciences despite being close to STEM education, presents high levels of stress and anxiety linked to ICTs. These differences among teachers from higher education institutions [72–76] also amplifies the fact, highlighted in the observational analysis, that training with ICTs is a major factor to protect these workers [88]. In this sense, UNESCO described the relevant preventative factors and how to decrease such prevalence, and highlighted that workers need training, updating the ICTs available, and supporting the continuity of adequate education [88]. Moreover, the bibliometric analysis showed that the quality of the observational studies is under 70% despite being indexed, underlining the need to further descriptive studies with higher methodological quality.

Another aspect identified in the bibliometric analysis was the fact that most of observational studies focused on STEM teachers at higher institutions previous to the pandemic, and therefore, further analysis during the current pandemic are needed. In this sense, the current observational analysis might provide more relevant data, although such information and its application in the education field (such as increasing the training with ICTs and its later analysis via experimental study) should be made with precautions based on the reduced number of participants. Despite the findings and application to the field, the current research also has limitations. The major limitation of this study is its small sample of teachers, although no previous research has focused only on STEM teachers during COVID-19 at the university level. This limitation is associated with the population and the rate of response from participants, being under 10%.

Moreover, another limitation from the methodology is the use of a survey based on perception and the cross-sectional design that limits the results to a timeframe. Besides, the data from university teachers has limited the results to the countries that participated, so the extrapolation of the data needs to be carefully carried out. Additionally, some personal data of the sample were not included, such as gender, number of children or their age, which could provide further information.

Additionally, since the research method was based on a mixed approach, another weakness of the methodology could be the choice of MeSH or other keywords not being included, which might have enclosed the number of publications and therefore, the possibility of framing the survey results into the current knowledge. Nonetheless, the current research based on a mixed-method has raised interesting questions about mental health and its relationship with the ICTs, taken in educational higher institutions environment during the pandemic, and e-learning education. Despite contract with the findings from the current observational analysis, whose findings indicated that STEM education or experience in STEM courses was not a definitive shielding factor against mental issues. In fact, the STEM teachers also suffered from psychological problems during the pandemic, which could be associated with the lack of previous experience with online learning [53]. Another aspect identified in the bibliographic analysis was the lack of studies carried out in the population selected (Spain or Ecuador), and the papers did not consider the lack of technical support as a stressor [72–76]. Additionally, another result was that the current investigations are more commonly reviews [85,86], being also more cited. The top publications focused on recommendations [87] to prevent mental issues, qualitative approaches, and little provided current data; being less common, the perspective of STEM teachers at university level. Other prior works indicated that the highest prevalence of work-related technostress among teachers (around 10%) was related to a specific age group (women from 30 to 39 years old with children), which could be related to training, working workload, and family chores, and the field in which the education is provided [73,87]. Thus, most works focused on analyzing prevalence and its relationship with the teachers' attitudes but did not include the teachers' perspective regarding obstacles such as the lack of ICTs [72–76]. Additionally, these articles (Table 5) focused on Turkey and pre-service faculty members, not including the STEM teachers as an independent group but studying this population in combination with other educators [72–76]. Additionally, one study focused on healthcare teachers [73] showed that lectures from health sciences despite being close to STEM

education, presents high levels of stress and anxiety linked to ICTs. These differences among teachers from higher education institutions [72–76] also amplifies the fact, highlighted in the observational analysis, that training with ICTs is a major factor to protect these workers [88]. In this sense, UNESCO described the relevant preventative factors and how to decrease such prevalence, and highlighted that workers need training, updating the ICTs available, and supporting the continuity of adequate education [88]. Moreover, the bibliometric analysis showed that the quality of the observational studies is under 70% despite being indexed, underlining the need to further descriptive studies with higher methodological quality. Another aspect identified in the bibliometric analysis was the fact that most of observational studies focused on STEM teachers at higher institutions previous to the pandemic, and therefore, further analysis during the current pandemic are needed. In this sense, the current observational analysis might provide more relevant data, although such information and its application in the education field (such as increasing the training with ICTs and its later analysis via experimental study) should be made with precautions based on the reduced number of participants. Despite the findings and application to the field, the current research also has limitations. The major limitation of this study is its small sample of teachers, although no previous research has focused only on STEM teachers during COVID-19 at the university level. This limitation is associated with the population and the rate of response from participants, being under 10%. Moreover, another limitation from the methodology is the use of a survey based on perception and the cross-sectional design that limits the results to a timeframe. Besides, the data from university teachers has limited the results to the countries that participated, so the extrapolation of the data needs to be carefully carried out. Additionally, some personal data of the sample were not included, such as gender, number of children or their age, which could provide further information. Additionally, since the research method was based on a mixed approach, another weakness of the methodology could be the choice of MeSH or other keywords not being included, which might have enclosed the number of publications and therefore, the possibility of framing the survey results into the current knowledge. Nonetheless, the current research based on a mixed-method has raised interesting questions about mental health and its relationship with the ICTs, taken in educational higher institutions environment during the pandemic, and e-learning education. Despite these limitations and based on the topic, timeframe, population, and sample size, including a few publications, the findings presented with the mixed-method could provide further knowledge in

this area. The results, mainly through the bibliographic analysis, highlight that previous studies were not focusing on STEM teachers and there was a lack of data in this specific population, as well as stressors that also affect these workers. A vital practical repercussion is the essential nature of training and adequate technical support as well as giving mental support to the workers in the educational sector.

6. Conclusions

Among university teachers, the anxiety and depression levels and their risk of developing them as a mental disorder from a sample of STEM Spanish and Ecuadorian teachers at university were highly elevated and linked to their perspective. One of the most relevant findings is that anxiety and depression can be linked to various obstacles, such as lack of training, resources, time, or research. The results showed that STEM teachers at university level perceived COVID-19, the imposition of using ICTs, the technological issues, the balance between family and work, and their perception of the lack of means as obstacles towards the mental issues among these workers. These results are fascinating since the teachers, independently of the country, indicated that their mental health and stress were high, caused by different factors related to technology. Other factors were also noteworthy, such as the impact of COVID-19, since these data indicated their relevance on mental health, although these factors were not conclusive in the risk of anxiety and depression. The second significant finding was that the described variables (e.g., training, or behavioral attitudes regarding ICTs) in most significant previous works were connected to a higher risk of stress and anxiety associated with technology. Another important finding that emerged from the bibliometric analysis was that most results focused on countries such as Turkey or the USA, with a lack of research carried out in Spain or Ecuador. Moreover, there was also a lack of observational analysis whose focus was determining factors linked to mental distress and risk factors. Most of the documents were reviews that analyzed the impact of ICTs and stress, and highlighted how STEM teachers have lower risk of mental issues, which could be not applicable in the current pandemic. These results of the previous observational studies, independently of the year or number of citations, in contrast with the observational data from the current research, did not analyze the effect of STEM education as a preventive factor related to the training of teachers. Finally, all these findings suggest that to decrease the prevalence of mental issues, greater compliance with the relevant measures, mainly training with ICTs, is needed, along with further research that focuses on whether such

actions are implemented.

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The data are available; please contact the authors.

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Appendix A

Table A1. Correlation and *p*-values between the variables of the bibliometric analysis.

Variables	Year	Number of Citations	Indexed	JCR of the Year of Publication	Quartile	Percentile	Continent	USA vs. Other Countries	The Year of the Pandemic	Median of the Year of Publication (2018)
Year	–	–	–	–	–	–	–	–	–	–
Number of citations	−0.39 ($p < 0.001$)	–	–	–	–	–	–	–	–	–
Indexed	−0.034 ($p = 0.67$)	0.5 ($p < 0.001$)	–	–	–	–	–	–	–	–
Journal of Citation Report of the year of publication	0.16 ($p = 0.045$)	0.38 ($p < 0.001$)	0.84 ($p < 0.001$)	–	–	–	–	–	–	–
Quartile	−0.083 ($p = 0.3$)	−0.42 ($p < 0.001$)	−0.84 ($p < 0.001$)	−0.98 ($p < 0.001$)	–	–	–	–	–	–
Percentile	0.084 ($p = 0.29$)	0.42 ($p < 0.001$)	0.84 ($p < 0.001$)	0.99 ($p < 0.001$)	−0.99 ($p < 0.001$)	–	–	–	–	–
Continent	0.12 ($p = 0.12$)	−0.16 ($p = 0.043$)	−0.21 ($p = 0.009$)	−0.24 ($p = 0.002$)	0.24 ($p = 0.002$)	0.25 ($p = 0.002$)	–	–	–	–
USA vs. other countries	−0.23 ($p = 0.003$)	0.15 ($p = 0.06$)	0.20 ($p = 0.011$)	0.16 ($p = 0.048$)	−0.18 ($p = 0.025$)	−0.18 ($p = 0.023$)	0.7 ($p < 0.001$)	–	–	–
The year of the pandemic	0.87 ($p < 0.001$)	−0.39 ($p < 0.001$)	−0.027 ($p = 0.73$)	0.14 ($p = 0.085$)	−0.07 ($p = 0.37$)	0.07 ($p = 0.4$)	−0.17 ($p = 0.037$)	0.22 ($p = 0.006$)	–	–
Median of the year of publication (2018)	0.88 ($p < 0.001$)	−0.43 ($p < 0.001$)	−0.08 ($p = 0.33$)	0.08($p = 0.32$)	−0.01 ($p = 0.9$)	−0.009 ($p = 0.9$)	0.17 ($p = 0.031$)	−0.21 ($p = 0.008$)	0.89 ($p < 0.001$)	–

Table A2. STROBE Checklist of the top five observational studies per item.

Study	1a	1b	2	3	4	5	6a	6b	7	8a	8b	9	10	11a	11b	12a	12b	12c
[72]	No	Yes	Yes	Yes	Yes	Yes	Yes	NP	Yes	Yes	NP	No	No	Yes	NP	Yes	Yes	No
[73]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NP	No	Yes	Yes	Yes	Yes	Yes	NP	Yes	No	No
[74]	No	Yes	Yes	Yes	Yes	No	No	NP	No	Yes	NP	No	No	No	NP	No	No	No
[75]	No	No	Yes	Yes	Yes	No	Yes	NP	No	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes
[76]	No	No	Yes	Yes	Yes	No	No	NP	No	Yes	NP	No	Yes	Yes	NP	No	No	Yes
Study	**12d**	**12e**	**13a**	**13b**	**13c**	**14a**	**14b**	**14c**	**15**	**16a**	**16b**	**16c**	**17**	**18**	**19**	**20**	**21**	**22**
[72]	No	Yes	No	No	No	No	No	NP	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No
[73]	Yes	No	Yes	Yes	No	Yes	Yes	NP	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
[74]	No	Yes	Yes	Yes	No	Yes	No	NP	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No
[75]	Yes	Yes	Yes	No	No	Yes	Yes	NP	Yes	No	No	No	Yes	Yes	Yes	No	Yes	No
[76]	No	Yes	No	No	No	No	No	NP	Yes	Yes	No	No	No	Yes	Yes	No	Yes	No

Note: Not applicable = NP; Strengthening the Reporting of Observational Studies in Epidemiology = STROBE Checklist.

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3

PROPUESTA DE UN MODELO STEM SOSTENIBLE EN EL CONTEXTO DE DOCENCIA UNIVERSITARIA: GAMIFICACIÓN Y TICS

La educación para la sostenibilidad se encuentra inmersa en los Objetivos de Desarrollo Sostenible (ODS) definidos por la Organización de las Naciones Unidas (ONU), específicamente en el objetivo 4:"Garantizar *una educación inclusiva, equitativa y de calidad y promover oportunidades durante toda la vida para todos*". Es decir, se concibe la formación de personas capaces de tomar decisiones responsables, conscientes de los retos globales y, de aplicar sus conocimientos para la resolución de problemas tecnológicos, sociales y ambientales en su entorno.

Las instituciones de educación superior en Europa deben continuar trabajando para responder a la sostenibilidad en sus planes de estudios, en concordancia con el modelo propuesto en el Espacio Europeo de Educación Superior (EEES) de la que España es miembro. Así mismo, Ecuador posee un modelo de enseñanza superior basados en los mismos principios que los establecidos en sistema EEES y por tanto equiparable en todos sus términos.

Las tecnologías de la información y la comunicación, TICs, han impactado en el sistema educativo y han promovido la utilización e inclusión de numerosas herramientas digitales que facilitan la creación de nuevos recursos educativos.

Las últimas tendencias en desarrollo TICs, entornos virtuales de aprendizaje (LMS) y aprendizaje inmersivo a través de realidad aumentada, y las metodologías activas y pedagogías basadas en ellas han favorecido a su vez el interés de los estudiantes fomentando la atención y el interés de éstos.
Dentro de estas herramientas softwares, la gamificación es una metodología activa que integra elementos basados en juegos. Existen numerosos estudios que demuestran su utilidad en el contexto educativo de enseñanzas básicas, sin embargo, a nivel de educación superior, los estudios centrados en su utilización son escasos, aunque, si se ha demostrado sus beneficios en las escasas investigaciones realizadas hasta la fecha.

Se ha comprobado que la gamificación contribuye a una mejora de la sostenibilidad de la educación debido a su impacto directo en ciencia, tecnología, ingeniería y matemáticas (STEM), ya que promueve el despertar de la curiosidad en el alumnado y por tanto su deseo de investigar y mejorar el conocimiento. De ello se deduce, que tiene la potencialidad de mejorar la motivación de los estudiantes en su proceso formativo, impulsa su participación, promueve el desarrollo de habilidades y comportamientos más sostenibles y mejora el rendimiento académico de los estudiantes.

Todos estos efectos positivos, descritos anteriormente, facilitan, a su vez, la motivación de los docentes en su tarea educativa, lo que se traduce en una mejora de sus condiciones de trabajo, en una motivación en el desarrollo de las mismas y por tanto en una promoción de su salud y bienestar.
Esto conduce a un sistema de educación más sostenible a nivel educativo, tecnológico y humano.

La inclusión de metodologías activas y TICs en el proceso de enseñanza tuvo un crecimiento exponencial en las primeras fases de la pandemia del COVID-19, en donde las instituciones de educación superior a nivel mundial implementaron planes de acción en la modalidad virtual. Esta experiencia, generada por factores externos, demostró la importancia de las TICs en los procesos educativos, especialmente en las modalidades de enseñanza a través de entornos virtuales y como elemento clave para la retroalimentación y comunicación.

Estos condicionamientos imprevisibles, permitieron realizar estudios sobre el uso e influencias de las TICs tanto a nivel docente como en el desarrollo del bienestar psicológico de profesores y estudiantes en los periodos pre y pots pandemia.
En base a las investigaciones realizadas y publicadas, se presenta la propuesta de un modelo parcial de docencia en Educación Superior (TICs y Gamificación) que responde al Objetivo 4 definido por la ODS y, que concibe la integración de las herramientas tecnológicas como parte del fortalecimiento de la

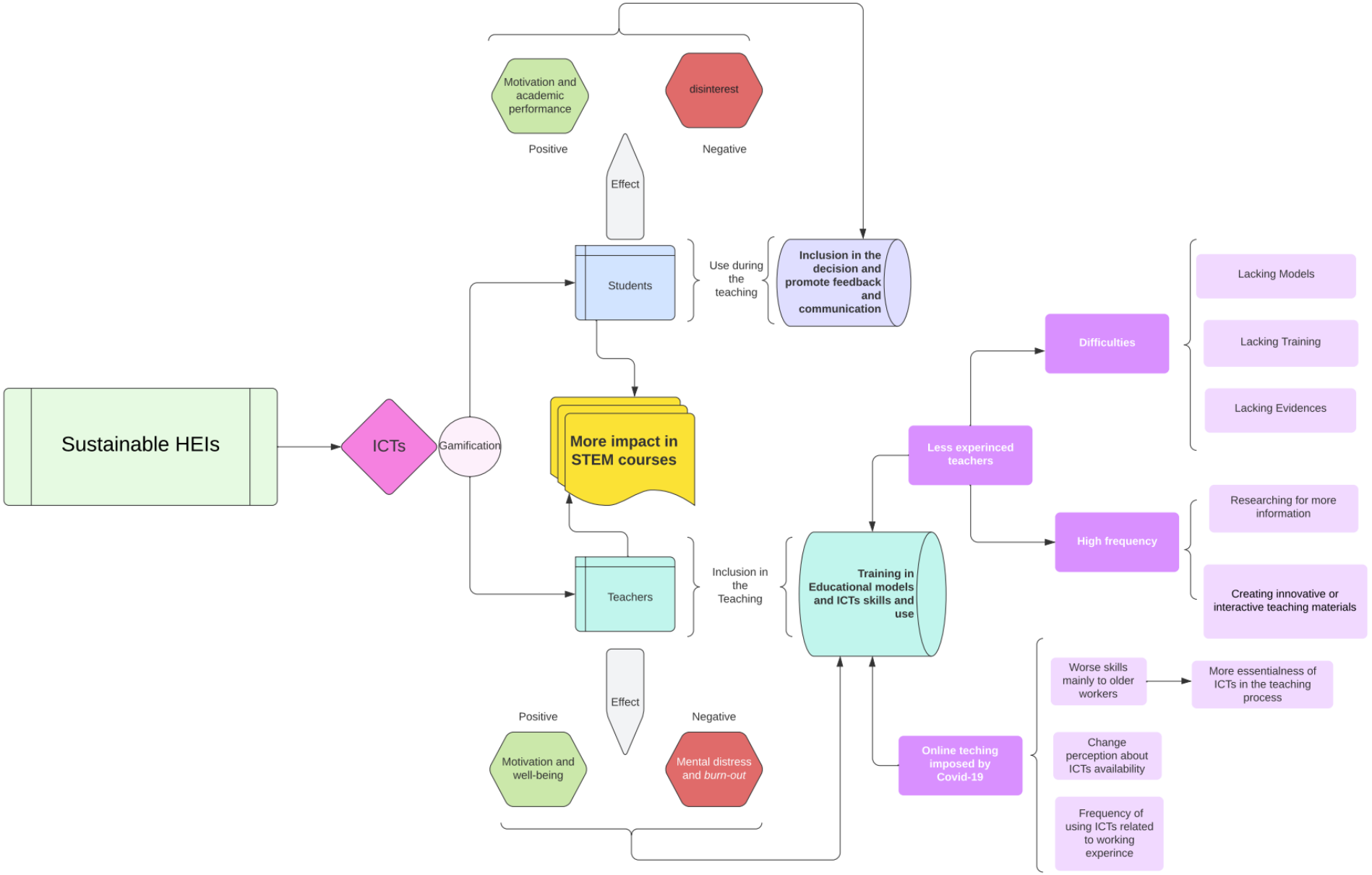
educación STEM en Universidades de Ecuador y España, contribuyendo a la sostenibilidad del sistema Universitario (Figura No.1) en estos países.

Para obtener un modelo más general que complemente al que a continuación se propone es necesario llevar a cabo el estudio centrado en los estudiantes, factores psicológicos y medioambientales, así como determinar la influencia de las redes sociales como herramientas metodológicas de gran proyección futura.

En el modelo (Figura 1), que se propone en este estudio, se presenta un esquema general aplicando los factores estudiados. Las tecnologías de la información y comunicación TICs tienen un papel fundamental por su impacto en el sistema educativo, brindando la oportunidad de incluir herramientas y programas para la creación de recursos educativos, entornos virtuales de aprendizaje y nuevas formas de aprendizaje. Además, han posibilitado la inclusión de nuevas metodologías activas como la gamificación que integra elementos basados en el juego y recompensas, con la capacidad de mejorar la motivación de los estudiantes en el proceso formativo, impulsar la participación activa, el desarrollo de habilidades y comportamientos más sostenibles tanto en estudiantes como en docentes.
Así mismo, se muestra la importancia de las TICs en los procesos educativos para soportar situaciones no previstas como lo fue la pandemia de COVID-19, en el que estas herramientas fueron la base para la enseñanza a través de entornos virtuales, lo que permitió mantener la retroalimentación y comunicación con los estudiantes.
Por otra parte, el modelo propuesto destaca la importancia y diferencia de la experiencia laboral, la carencia de modelos estructurados para la aplicación en el aula y la capacitación continua que permita mitigar los obstáculos para la integración de las TIC. No obstante, el cambio abrupto que se produjo de la educación durante la pandemia empeoro las habilidades en TIC en los docentes, ante las exigencias del momento, desencadenando como efecto negativo en los docentes desórdenes emocionales como depresión, ansiedad y tecnoestrés.

Por último, cabe destacar que para obtener un *Sistema Sostenible de Educación Superior* el rol de los docentes es fundamental e imprescindible. Por ello es imperativo de una parte brindar capacitación a los docentes en modelos que integren las TICs y mejoren el desarrollo de sus habilidades tecnológicas, por otra ofrecérsele una supervisión y ayuda constante en cuanto a su actualización y condiciones de trabajo que contribuyan a su bienestar físico y psíquico.

Figura 1. Modelo STEM sostenible en el contexto de docencia universitaria: gamificación y tics



4

CONCLUSIONES

En primer lugar, se realizó una revisión bibliométrica de la producción científica relacionada con el impacto de las TICs, gamificación y bienestar emocional en Instituciones de Educación Superior, centradas en sus docentes y en el crecimiento en campos STEM, obteniendose los siguientes resultados:

- Respecto a la hipótesis H.1.1, se puede concluir que la producción científica relacionada con la gamificación radica en estudios experimentales a partir del año 2018, principalmente investigaciones con enfoque cualitativo en donde el desarrollo más significativo se encuentra relacionado con el incremento de la motivación en los estudiantes, mejora en el rendimiento académico, participación y comportamientos sostenibles.

- Respecto a la hipótesis H1.2, en este estudio se evidencia, a través de la investigación científica, la utilización de la gamificación como herramienta promotora de bienestar social en diversos campos incluidos la educación y la salud, mejorando la motivación, la autoestima y rendimiento académico en los estudiantes, creando en la IES entornos saludables y sostenibles.

En segundo lugar, se realizó un estudio comparativo a través de una encuesta cualitativa en línea, con el objetivo de determinar los factores de inclusión y uso de las TICs en las instituciones de educación superior en dos distintos momentos: (pre y post confinamiento), obteniendo los siguientes resultados:

- Respecto a la hipótesis H2.1: se puede concluir que la integración de las TIC en el sistema educativo es clave para crear instituciones educativas sostenibles, siendo de gran importancia para el beneficio de los docentes universitarios, sus habilidades en TIC y su impacto ante situaciones extraordinarias como el COVID-19. En este estudio se evidencio como la falta de modelos específicos, de recursos disponibles y de la ausencia de capacitación de los docentes para el uso e inclusión de las TICs y de las metodologías activas como la gamificación, fueron los principales obstáculos encontrados, especialmente en los docentes con mayor experiencia.

- Con respecto a la hipótesis H2.2 se puede concluir que existe una relación entre la experiencia laboral y el uso de las TICs. En este estudio se evidenció que los docentes con menor experiencia dedican más tiempo al uso de las TICs, otorgando mayor importancia y criticidad a su integración, independientemente del país. Además, los resultados que compararon el pre y post confinamiento evidenciaron que los docentes con menor experiencia, a pesar de contar con disponibilidad de recursos y herramientas TICs, carecían de modelos para su correcta integración. Así mismo, se comprobó que después del confinamiento cambio la percepción de los docentes con mayor experiencia en relación con la imprescindibilidad de las TICs en el proceso de enseñanza y aprendizaje.

En tercer lugar, se analizó la influencia de la tecnología y el covid-19 en docentes con alta experiencia en educación STEM en las instituciones de educación superior, obteniendo los siguientes resultados:

- Respecto a la hipótesis H3.1 el estudio mostró que los docentes STEM a nivel universitario percibieron como obstáculos, para desarrollar su labor docente, diferentes factores tales como: el COVID-19, la imposición del uso de las TIC, los problemas tecnológicos, el equilibrio entre familia y trabajo, y la percepción de la falta de medios, lo que provocó en un alto porcentaje de docentes altos los niveles de ansiedad, depresión y su riesgo de desarrollarlos como un trastorno mental.

- Respecto a la Hipótesis H3.2 el estudio demostró que los docentes universitarios STEM, españoles y ecuatorianos, presentaban altos niveles de ansiedad y estrés que se relacionaba con su percepción de la metodología de trabajo on-line. El estudio evidenció como los docentes percibían la relación de la ansiedad y la depresión con diversos obstáculos, como la falta de formación, recursos, tiempo o investigación, independientemente del país, provocados por diferentes factores relacionados con la tecnología.

- Respecto a la hipótesis H3.3 se pudo observar que la pandemia de covid-19 tuvo gran relevancia en la salud mental de los docentes. En este estudio que utilizo una investigación mixta sustenta el impacto de las TIC y el estrés, y destaca cómo los docentes de STEM tienen un menor riesgo de desarrollar problemas mentales, como parte del efecto de la educación STEM como factor preventivo relacionado con la formación de docentes.

Por último, en la hipótesis H4, se puede mencionar que, en base a los resultados obtenidos en los estudios anteriores, se ha propuesto un nuevo modelo STEM en el que se ha destacado el papel de las TICs y la gamificación, formación continuada del profesorado y bienestar del mismo para la consecución de los objetivos de sostenibilidad del sistema educativo superior.

5

FUTURAS LÍNEAS DE INVESTIGACIÓN

El tema tratado en esta tesis en el que se trata sobre el desarrollo de nuevos modelos para la Enseñanza superior STEM y su portabilidad a diferentes centros y Universidades de distintos países, presenta gran interés y futuro. La doctoranda considera que el modelo propuesto en el que se han tenido en cuenta tanto factores tecnológicos, TICs y Gamificación, como factores sociales y medioambientales, condicionados por los usuarios como son profesores y alumnos, es susceptible de ser ampliado al incluir nuevas herramientas tecnológicas como son las redes sociales, WhatsApp, TikTok, Facebook etc , y Realidad Virtual y Aumentada que permite la inmersión en actividades vividas como realidades. Se propone:

1. Utilizar redes sociales como herramientas de tutorías individuales y grupales o como técnicas de trabajo grupal dirigido.
2. Proponer la utilización de herramientas de Realidad Virtual y Aumentada que permite trabajar con laboratorios virtuales que asemejan y complementan Laboratorios Reales difíciles de implementar por su complejidad y coste.
3. Valorar la respuesta educativa y psicosocial de alumnos y profesores mediante encuestas validadas que determinan la disponibilidad de las herramientas y de la preparación para utilizarlas.
4. Determinar el nivel de stress de los usuarios y vulnerabilidad ante las nuevas propuestas metodológicas.
5. Estudiar la Sostenibilidad del Sistema Educativo STEM al incluir estas nuevas herramientas tecnológicas dentro de un modelo educativo global.
6. Ampliar el modelo pedagógico STEM propuesto en esta TESIS teniendo en cuenta todos los factores anteriormente propuestos.

6

CONTRIBUCIONES CIENTÍFICAS

Se indican a continuación toda la producción investigadora generada en la presente tesis.

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1. Navarro-Espinosa, Johanna A., Manuel Vaquero-Abellán, Alberto-Jesús PereaMoreno, Gerardo Pedrós-Pérez, Pilar Aparicio-Martínez, and Mª P. Martínez-Jiménez. 2021. "The Higher Education Sustainability before and during the COVID-19 Pandemic: A Spanish and Ecuadorian Case" *Sustainability* 13, no. 11: 6363. https://doi.org/10.3390/su13116363

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