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Fostering Innovation in K-12 Education: A Systematic Review of the Integration of Design Thinking within Educational Technology

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ABSTRACT

Design Thinking has surfaced as a skill set as well as mindset phenomenon renowned for its problem-solving efficacy in the realms of business, engineering, and corporate endeavors. Nevertheless, the degree to which these skills and mindsets can be harnessed to benefit the field of Education, particularly within the domain of Educational Technology (edtech) at the K-12 educational level, warrants examination. In order to meet this inquiry, the present study conducts a Systematic Literature Review aimed at identifying potential gaps in applying Design Thinking principles within the sphere of Educational Technology, with the objective of making these principles accessible to all stakeholders involved in K-12 education. A comprehensive analysis encompassed 133 articles retrieved from SCOPUS as well as Web of Science (WoS) databases. Moreover, these articles underwent a thorough filtering process following the PRISMA Framework, including 32 articles for final-stage analysis. These 32 articles explored three overarching themes: (1) Design Thinking in education, (2) Student-Centered Learning Environments, and (3) Innovative Educational Technologies. In summation, Design Thinking possesses the potential to enhance the field of Educational Technology, equipping it with the requisite knowledge, skills, values, and mindset necessary to fortify 21st-century-oriented pedagogical practices for K-12 students. Furthermore, this research encourages subsequent investigations by fellow scholars to adapt and refine Design Thinking methodologies in facilitating creative and innovative approaches to Educational Technology and Science, Technology, Engineering, and Mathematics (STEM)-based instruction as well as learning within K-12 educational settings.

Keywords:
Design thinking; educational technology; edtech; K-12; innovation; student-centered.

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1. Introduction

The emergence of Design Thinking as well as educational technology (edtech) is transforming primary and secondary education [1,2]. Design thinking is a problem-solving methodology grounded in empathy as well as creative thinking, which has moved beyond industrial design to impact pedagogy, as described in Figure 1. It encourages educators and students to rethink traditional teaching and learning paradigms, fostering [3-5]. Educational technology encompasses a range of digital tools, revolutionizing the classroom and enabling personalized learning experiences [6–8]. It extends access to educational resources beyond physical classrooms and empowers educators with data-driven insights [9]. This shift in education is characterized by increased engagement, accessibility, and adaptability [10,11]. Traditional education also evolves due to globalization and technological advancements [12,13]. Classrooms are becoming more flexible, adapting to the changing needs of students and the demands of a holistic education [14,15]. Institutions are no longer isolated; they are interconnected centers of learning that transcend geographical and cultural boundaries [16].

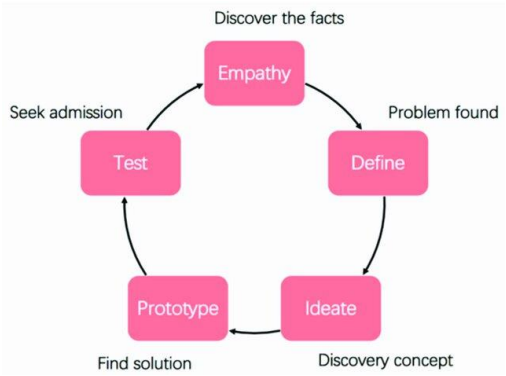

Fig. 1. Relationship between creative problem-solving and design thinking [17]

1.1 Literature Review

The convergence of design thinking and educational technology (edtech) is a prominent theme in contemporary education, as shown in Figure 2 [18,19]. Design thinking, rooted in industrial design and innovation, emphasizes empathy, creativity, and iterative ideation [20–24]. It transforms pedagogical practices and engages students in co-creating solutions [25,26]. Educational technology has reshaped education, offering digital tools for personalized learning, expanded access, and data-driven instruction [27-30], enhancing student engagement, accessibility, and adaptability [31–33]. Design thinking and edtech intersection enhances curriculum development, user experience, and student engagement [34–37]. However, challenges exist in integrating design thinking into edtech, requiring a shift in educator mindset and professional development [38–41]. These challenges provide opportunities to improve teacher readiness and effective integration [42]. As education evolves due to globalization, technology, and holistic education, exploring how design thinking and edtech can synergize is essential for fostering innovation and benefiting student outcomes [43–47] .

Fig. 2. Design Thinking helps link to educational technology to connect students to understand basic computing through the workshop of website housing and tutorial [19]

This systematic literature review explores the intersection of design thinking, educational technology, and the evolving educational landscape [48,49]. It aims to answer the benefits of incorporating design thinking into integrating edtech with regard to student learning outcomes, innovation-driven, and pedagogical effectiveness. This review seeks to offer valuable perspectives on researchers, educators, policymakers as well as educational stakeholders [50]. It aims to guide innovation and contribute to discussions about pedagogy in an era characterized by rapid change and innovation [51], which inculcates the creative confidence model mentioned by Rauth *et al.,* [52], as shown in Figure 3. Subsequent sections will delve into the key themes, emerging findings, and trends from existing scholarly literature, shedding light on the promising paths toward a more innovative, adaptable, and effective educational landscape [49].

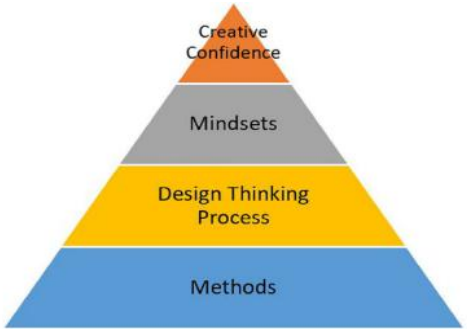

Fig. 3. Creative confidence model [18,52]

2. Methodology

The Systematic Literature Review process is carried out using the PRISMA Framework, which involves rigorous review through three main phases described in subsections 2.1 Identification, 2.2 Screening, and 2.3 Eligibility. At the end of the data formulation, 2.4 Data Abstraction and Analysis describes the PRISMA Framework-based review.

2.1 Identification

In the process of curating a set of pertinent research for this study, the systematic review procedure encompasses 3 pivotal stages [48,50]. The inaugural phase entails recognizing

keywords and exploring interconnected, analogous terminology through reference to thesauri, lexicons, encyclopedias, and antecedent scholarly investigations. Following the determination of all pertinent keywords, search strings were formulated for querying the Scopus as well as WoS databases, as illustrated in Table 1. During the initial phase of the systematic review project, this research effectively gathered a combined total of 133 academic articles from the two databases.

Table 1
Search String

Database	Search String
Scopus	TITLE-ABS-KEY(("Design Thinking") AND (educational AND technology) AND ("School" or "K*12" or "classroom" or "Primary School" or "Middle School" or "High School")) AND (LIMIT-TO (SRCTYPE,"j") OR LIMIT-TO (SRCTYPE,"p")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp")) AND (LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2023)) AND (LIMIT-TO (LANGUAGE,"English")) Access Date: 16 September 2023
WoS	("Design Thinking") AND (educational AND technology) AND ("School" OR "K*12" OR "classroom" OR "Primary School" OR "Middle School" OR "High School") (Topic) and 2022 or 2023 or 2021 or 2020 or 2019 (Publication Years) and Article or Proceeding Paper (Document Types) and English (Languages) Access Date: 16 September 2023

2.2 Screening

During the initial screening phase, redundant papers were removed, excluding 15 articles in the first stage. Consequently, the second screening stage comprised the evaluation of 133 papers based on a set of inclusion and exclusion criteria established by scholars. The primary criterion employed was the nature of the literature, which prioritized research articles as the main source of practical insights. Additionally, this encompassed the exclusion of reviews, systematic reviews, meta-analyses, meta-syntheses, book series, books as well as book chapters that were not aligned with the latest research. It is worth noting that this selection process was delimited to English-language publications and focused on the preceding 5-year period from the year 2019 to 2023. A total of 70 publications were excluded according to these particular criteria.

2.3 Eligibility

In the third phase, referred to as eligibility assessment, a number of 48 articles were compiled. The titles and essential content of these articles underwent a comprehensive evaluation to confirm that they met the inclusion criteria and aligned with the current research objectives. Hence, 16 articles were excluded from the assessment for not meeting features such as title not significant, abstract not related to the review objective, and out-of-field reports. Finally, there are 32 articles accessible for examination refer to Table 2:

Table 2
The selection criterion of searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2019-2023	< 2019
Literature type	Journal (Article), Conference Proceedings	Book chapters, Book Series, Review
Publication Stage	Final	In Press

2.4 Data Abstraction and Analysis

In this study, an integrative analysis approach was employed to amalgamate diverse research methodologies, encompassing qualitative, quantitative as well as mixed methods. The primary objective was to identify relevant topics and subtopics related to Design Thinking applied in educational technology for K-12 teaching and learning atmosphere. The data collection process involved a meticulous review of 32 publications, extracting pertinent information for the study's topics. Three key themes emerged: "Design Thinking in Education", “Student-Centered Learning Environments”, and "Innovative Educational Technologies", which were further developed along with associated themes and ideas through collaboration among the authors. All articles divided according to theme are described in Table 3. A comprehensive record was consistently kept during the data analysis process to record analyses, discoveries, inquiries, and any pertinent details. The authors also engaged in discussions to address any inconsistencies in the theme development process, ensuring the themes' coherence. The analysis was reviewed by experts in Technology Pedagogical and Content Knowledge (TPACK), Educational Technology (EdTech), Design Thinking (DT), and STEM (Science, Engineering, Mathematics, and Technology) Education to establish domain validity, ensuring significance, clarity as well as the suitability of every sub-theme. The expert review phase involved incorporating feedback and professional judgments into the analysis, leading to adjustments to enhance the study's validity and reliability. Figure 4 explains the process implemented under the PRISMA Framework:

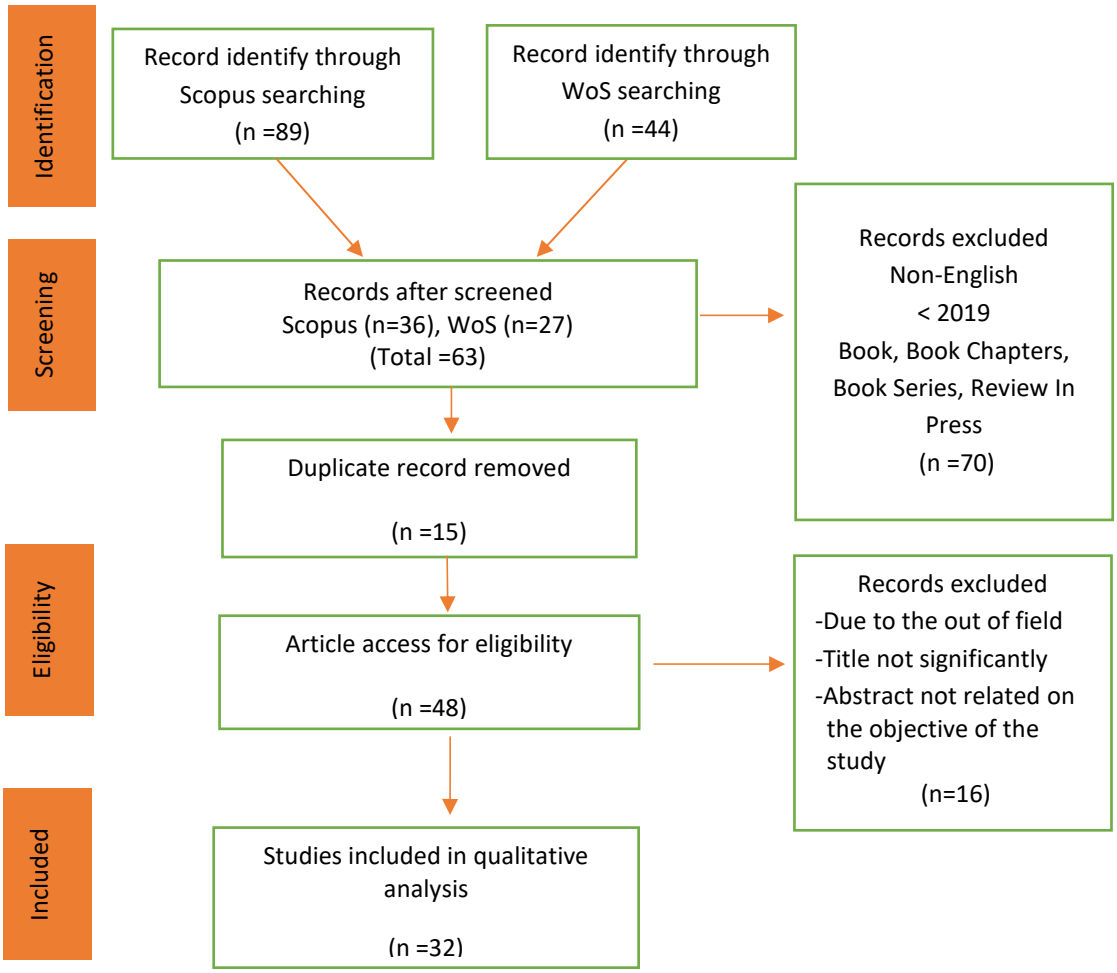

Fig. 4. Flow diagram of the proposed searching study [53]

3. Result and Finding

Based on 32 articles filtered based on the PRISMA Framework, three main themes were identified consists of (1) Design Thinking in Education, (1) Student-Centered Learning Environments dan (3) Innovative Educational Technologies.

3.1 Theme 1: Design Thinking in Education

Design thinking in education is a student-centered problem-solving approach, fostering creativity, empathy, and critical thinking for effective learning solutions. Table 3 emphasizes articles that related about application of Design Thinking in educational perspectives:

Table 3
Theme 1: Design Thinking in Education

Authors	Title	Source Title	Methodology	Findings
Kijima R.; Sun K.L. [54]	'Females Don't Need to be Reluctant': Employing Design Thinking to Harness Creative Confidence and Interest in STEAM	International Journal of Art and Design Education	The global gender gap in STEAM education is prominent in Japan; a three-day design-thinking-based curriculum empowers young females.	After a design thinking workshop, middle school girls showed heightened STEAM interest, creativity, empathy, and collaboration. Design thinking encourages female involvement in STEAM disciplines.
Ladachart L.; Khamlarsai S.; Phothong W. [55]	Cultivating a Design Thinking Mindset in Educationally Disadvantaged Students Using a Design-based Activity	International Journal of Innovation in Science and Mathematics Education	The study included 18 rural ninth-graders, pre/post Likert-scale questionnaires, classroom observations, and focus group interviews. Quantitative data used the Wilcoxon signed-rank test, and qualitative data analyzed thematically.	Results show improved comfort in solving engineering problems but no significant changes in other design thinking mindset aspects (empathy, collaboration, learning orientation, creative confidence). Contextual analysis considered the activity implementation.

Authors	Title	Source Title	Methodology	Findings
Harris, P [56]	Design Thinking As A Research Method To Delimit The Requirements Of An Interactive Environment For Learning English In Early Childhood Through Augmented Reality	Edulearn19: 11th International Conference On Education And New Learning Technologies	Two questionnaires were distributed to school executives and teachers in 25 Barranquilla, Colombia preschools. Qualitative SPSS analysis emphasized the importance of technology integration for curriculum and pedagogical improvement.	The study highlights the user-friendly design's significance, especially for tech-inexperienced teachers in low-income schools. Augmented reality is recommended for classroom use, influencing the design of an interactive English learning environment for early education in Barranquilla.
Tramonti M.; Dochshanov A.M.; Zhumabayeva A.S. [57]	Design Thinking as an Auxiliary Tool for Educational Robotics Classes	Applied Sciences (Switzerland)	The approach blends Design Thinking with Educational Robotics in secondary schools. It begins by gathering and examining teachers' survey data to assess Design Thinking integration in the current school curriculum.	The study then applies this framework in an educational context to address identified weaknesses, integrating Educational Robotics (ER) and Design Thinking (DT) classes within secondary school settings.
Öztürk A.; Korkut F. [58]	Design thinking customized to support STEM teachers: Co-developing and implementing STEM activities for fifth graders in Turkey	International Journal of Technology and Design Education	Action research was undertaken with fifth-grade teachers and students, using qualitative methods such as co-design workshops, focus groups, interviews, and observations for data collection.	The study found that restructuring STEM activity designs as a specified Design Thinking process supports teacher collaboration, interdisciplinary integration, and student-relevant activities, resulting in a robust learning experience.
Videnovik M.; Vold T.; Kionig L.; Trajkovik V. [59]	Design thinking methodology for increasing the quality of experience of augmented reality educational games	2019 18th International Conference on Information Technology Based Higher Education and Training, ITHET 2019	The methodology guides educational game creation, addressing student needs and aiming for specific learning outcomes. Illustrated with an augmented reality prototype.	Structuring STEM activity design using Design Thinking fosters teacher collaboration, interdisciplinary integration, and student-centered activities, enhancing the overall learning experience.

Authors	Title	Source Title	Methodology	Findings
Elwood, K; Jordan, ME [60]	Development of the Design Thinking and Instructional Lessons (DTAIL) model: a creative approach for teachers	Etr&D-Educational Technology Research And Development	Phase I introduces Design Thinking literature and the initial model. Phases II and III describe design studies involving STEM K-12 teachers.	Suggested enhancements for teacher-driven instructional design incorporating Design Thinking models involve ensuring clarity in the stages, encouraging iteration, reflection and fostering adaptability, which should align with teachers' methodologies.
Arbieto-Batallanos C.E.; Villanueva-Montoya L.D.; Chavez-Ponce D.S.; Alfonte-Zapana R.; Córdova-Martínez M.D.C. [2]	Mobile application based on design thinking for teaching kinematics	CEUR Workshop Proceedings	The proposal was executed in collaboration with the Antonio José de Sucre Educational Institution and the National University of San Agustín. It involved a selected group of 24 students aged 15 to 18 in the 5th year of their secondary-level studies.	Design Thinking is recommended to develop a user-friendly kinematics teaching app. Its success will be assessed through fifth-year high school students' acceptance.
Wu Q.; Lu J.; Yu M.; Lin Z.; Zhan Z. [61]	Teaching Design Thinking in a C-STEAM Project: A Case Study of developing the Wooden Arch Bridges' Intelligent Monitoring system	ACM International Conference Proceeding Series	H Elementary students learned empathy through bridge documentaries, constructed bridges, and designed an Intelligent Monitoring system.	By conducting classroom observations and post-school interviews, we determined that students had a favourable encounter with the culture of Chinese wooden arch bridges, leading to the cultivation of their design thinking skills.
Liu X.; Gu J.; Xu J. [62]	The impact of the design thinking model on pre-service teachers' creativity, self-efficacy, inventive problem-solving skills, and technology-related motivation	International Journal of Technology and Design Education	A quasi-experimental study with 70 pre-service teachers using Design Thinking Activities in a 12-week MET course.	The study identified disparities in tech motivation, creativity, and problem-solving between groups; integrating Stanford Design Thinking improved skills.

3.2 Theme 2: Student-Centered Learning Environments

Within the framework of design thinking, student-centered learning emphasizes tailoring education to individual needs, cultivating empathy, innovation, and personalized learning experiences. Table 4 compiles articles on this approach:

Table 4
Theme 2: Student-Centered Learning Environments

Authors	Title	Source Title	Methodology	Findings
Valentim, S; Freire, C [63]	A Perfect Learning Day: Perceptions of Secondary School Students about the Ideal School	9th International Conference The Future Of Education	A qualitative study inspired by Design Thinking collected student input on an ideal school day, revealing valuable insights.	Students envision an ideal school day with innovative teaching, flexible schedules, diverse classroom layouts, and tailored teacher support, matching their ideal school perceptions.
Shipepe A.; Uwu-Khaeb L.; De Villiers C.; Jormanainen I.; Sutinen E. [64]	Co-Learning Computational and Design Thinking Using Educational Robotics: A Case of Primary School Learners in Namibia	Sensors	Namibian boarding school held a 2-day robotics workshop, arming novices with Arduino for computational and design thinking.	Implementing this approach in classrooms empowers primary students with computational and design thinking, preparing them as 4IR tech creators.
Tsortanidou X.; Daradoumis T.; Barberá E. [65]	Connecting moments of creativity, computational thinking, collaboration, and new media literacy skills	Information and Learning Science	This paper presents a pedagogical model that aims at bridging creativity with CT, collaboration, and new media literacy skills.	This model integrates computational thinking, collaboration, and creativity in low-tech settings, emphasizing their importance in education.
Motschnig R.; Pfeiffer D.; Gawin A.; Gawin P.; Steiner M.; Streli L. [66]	Enhancing stanford design thinking for kids with digital technologies: a participatory action research approach to challenge-based learning	Proceedings - Frontiers in Education Conference, FIE	Qualitative survey analysis and focus group insights align with teachers' perspectives, offering a comprehensive understanding of the topic.	Developing digital competencies necessitates nurturing personal and social skills, with essential teacher involvement. This informs teacher education and international research, promoting cross-border educational enhancements.
Jovanovic V.M.; McLeod G.; Alberts T.E.; Tomovic C.;	Exposing students to STEM careers through hands-on activities with	ASEE Annual Conference and Exposition,	Delivered to 320 9th and 10th-grade students in four sessions, each with 80 participants, since	This research explores the versatile role of autonomous robots, particularly in STEM education. This study examines

Authors	Title	Source Title	Methodology	Findings
Popescu O.; Batts T.; Sandy M.L. [67]	drones and robots	Conference Proceedings	2016.	three robotics sessions conducted as part of a summer program for high school students at Old Dominion University, which is a component of the BLAST project under the Virginia Space Grant Consortium, aimed at fostering scientific and technological leadership.
Di Prete, B; Rebaglio, A; Crippa, D; Lonardo, E [68]	Lamp&D: A Design-Driven Process For A Collaborative And Playful Learning Experiment In The Middle School	12th International Conference Of Education, Research And Innovation (Iceri2019)	The Lamp&d project produced a collaborative table lamp prototype through university-middle school collaboration. It employed design thinking, problem-based learning, and playing cards to foster creativity, digital fabrication technology introduction, and hands-on learning, culminating in a physical prototype through FabLab collaboration.	A collaborative on-field research project in Milan involved a seventh-grade class, uniting a middle school and a university. It promoted design thinking, innovative teaching methods, Industry 4.0 technologies, and co-design practices.
Stork, MG [3]	Supporting Twenty-First Century Competencies Using Robots and Digital Storytelling	Journal Of Formative Design In Learning	Sixteen students in a three-week summer camp used Sphero Bot robots to design interactive stories, collecting data through classroom observations, student reflections, and artifacts.	This case study aligns with the P21 Framework, emphasizing two domains: learning and innovation skills as well as media, information, and technology literacy skills. It pinpoints five student competencies in these areas and concludes that using robots for interactive storytelling promotes the cultivation of 21st-century skills.
Herron J.; Wolfe K.A. [69]	University Innovation Hubs & Technology-Enhanced Learning in K12 Environments	TechTrends	Anderson University's innovation hub initiated professional development for K12 educators in design thinking and emerging technologies, culminating in a master's program aligning with	The article examines the development and alignment of external programming, emphasizing practitioner-faculty's role in fostering professional communities. It also discusses organizational benefits and

Authors	Title	Source Title	Methodology	Findings
			educational technology standards. Administered outside traditional academic units, it offers unique external programming.	future research opportunities.

3.3 Theme 3: Innovative Educational Technologies

Design thinking enhances Innovative Educational Technologies by empathizing with users, defining problems, ideating solutions, prototyping, and iterating for user-centered improvements. All articles discussing this theme are arranged in Table 5:

Table 5
Theme 3: Innovative Educational Technologies

Authors	Title	Source Title	Methodology	Findings
Segura, A; Agromayor, JA; Conde, A [70]	Consolidating The Digital Educational Transformation In Andalusia	14th International Technology, Education And Development Conference (Inted2020)	The project employs various methodologies for different project phases, including design thinking, Lean IT, BPM, TOGAF, Scrum, ITIL, PMP, and OPPM, ensuring effective implementation and testing of new services.	Andalusian Digital Education Ecosystem: Personalized learning, digital classrooms, content access, AI-driven support, continuous improvement.
Phumphongkhochasorn, P [71]	Development Of Instructional Model Based On Design Thinking And Reflective Practice Approaches In Creating Innovative Student Educational Administration In The Field Of Educational Administration Innovation, College Management Innovation Rajamangala University	International Journal Of Early Childhood Special Education	The study used design thinking and reflection in two phases, involving expert input, to develop a teaching model for educational administration innovation. The evaluation included validity and suitability assessment, analyzed statistically.	This study suggests an innovative educational administration model with five stages, emphasizing design thinking and reflection. Understanding the Instructional Model Manual is crucial for successful implementation.

Authors	Title	Source Title	Methodology	Findings
	Of Technology Rattanakosin			
Kim J.-Y.; Seo J.S.; Kim K. [72]	Development Of A Novel-Engineering-Based Maker Education Instructional Model	Education And Information Technologies	The study presents an instructional model for innovative maker education in rural elementary schools, developed through literature analysis, expert review, and practical validation, emphasizing the improvement of students' maker mindset.	The instructional model is tailored for rural schools, emphasizing affordability and problem-solving skills, fostering a maker mindset, and merging literature and engineering in student projects.
Churchill N. [73]	Development Of Students' Digital Literacy Skills Through Digital Storytelling With Mobile Devices	Educational Media International	This paper discusses a project evaluating primary school students' digital literacy skills through mobile-based digital storytelling. Students conducted research, analyzed data, and created digital stories, showcasing their research, design thinking, and digital literacy skills.	Mobile technology-based digital storytelling promotes digital literacy skills in students by enabling flexible information access, reflective thinking, idea expression, and peer and teacher feedback.
Hogan, MJ; Barton, A; Twiner, A; James, C; Ahmed, F; Casebourne, I; Steed, I; Hamilton, P; Shi, SP; Zhao, Y; Harney, OM; Wegerif, R [74]	Education For Collective Intelligence	Irish Educational Studies	The study emphasizes project-based learning as a solid foundation for Creative and Innovative (CI) education, accommodating diverse CI behaviors like swarm, stigmergy, and collaboration.	The paper discusses using Creative and Innovative (CI) technologies in education, emphasizing project-based learning to foster CI behaviors, collaboration, and adaptability.

Authors	Title	Source Title	Methodology	Findings
Johnson E.K.; Salter A. [75]	Embracing Discord? The Rhetorical Consequences Of Gaming Platforms As Classrooms	Computers And Composition	Discord, originally for gaming, is now popular in academia. This study examines its impact on norms and expectations in educational settings, drawing from academic experiences.	Platform disruptions affect aesthetics, organization, and communication, impacting education and conferences and raising concerns about harmful norms.
Andersen H.V.; Pitkänen K. [76]	Empowering Educators By Developing Professional Practice In Digital Fabrication And Design Thinking	International Journal Of Child-Computer Interaction	The study examines Discord's use in academic settings and its impact on established norms. It employs software studies and design thinking methodologies.	The study identifies five key stakeholders in FabLab@SCHOOLdk, which enables DT and DF in schools with a 1:1:1 model.
Jones H. [77]	Intersectional Design Cards: Exploring Intersecting Social And Environmental Factors Across Four Levels Of Design	Journal Of Writing In Creative Practice	The article explores 'Intersectional Design Cards,' a tool from Stanford's d.school, addressing tech design inequalities. Useful for professionals and adaptable to education.	This article integrates intersectionality research with design thinking using card prototypes, tested with students for design concepts.
Paico-Campos M.M.; Huamaní E.L.; Delgado A. [78]	Mobile Application Based On Design Thinking For Teaching Kinematics	International Journal Of Emerging Technology And Advanced Engineering	The research employed a hybrid methodology, combining Design Thinking and Soft Systems, with the Moqups tool chosen for its suitability in this project's development.	The study produced a mobile app for teaching illiterate individuals with effective methods, emphasizing edtech's classroom potential.
Bastida L.; Cea G.; Moya A.; Gallego A.; Gaeta E.; Sillaurren S.; Barbosa P.; Souto S.; Rodrigues E.; Torrego-Ellacuria M.; Triantafyllidis A.; Alexiadis A.; Votis K.; Tzovaras D.; Rocha C.; Alves L.; Malo P.; Mateus M.; Ferreira F.;	Promoting Obesity Prevention And Healthy Habits In Childhood: The Ocariot Experience	IEEE Journal Of Translational Engineering In Health And Medicine	The research utilizes a continuous co-creation process within the Design Thinking Methodology, involving children, educators, and healthcare professionals. It identifies user needs and technical requirements for an IoT platform based on microservices.	The study uses IoT to combat childhood obesity (ages 9-12) by involving kids, families, and educators. Validation in Spain, Greece, and Brazil resulted in a 75.5% obesity reduction in the intervention group, showing promise for global health.

Authors	Title	Source Title	Methodology	Findings
Arredondo M.T. [79]				
Alam M.; Haque M.S.; Tripathi A.; Vainionpää F. [80]	Prototyping A Gamified System To Persuade School-Age Children In Developing Countries: Using Kahoot In Online Environments	CEUR Workshop Proceedings	The study explores a gamified learning system using Kahoot for socio-economically disadvantaged children, with initial results favoring reward-based tasks. Future plans include applying Cognitive Social Learning Theory and conducting experimental studies.	The study reveals primary students prefer rewards in Kahoot math gamification. Future plans include applying Cognitive Social Learning Theory and conducting learning experiments.
Zapana R.A.; Del Carmen Córdova Martínez M.D.C. [81]	Sensor-Based Mobile Application For Teaching Physics To Regular Basic Education Students	ACM International Conference Proceeding Series	This project develops a mobile app for teaching physics using sensors, emphasizing portability and simplicity in experiments. Design thinking principles guide its creation, focusing on standardized interactions for effective teaching.	This innovation simplifies educational material creation, encouraging the use of mobile resources. It allows educators to focus on content design, fostering innovation through sensor interactions and improving educational content quality.
Lin X.-F.; Chen L.; Chan K.K.; Peng S.; Chen X.; Xie S.; Liu J.; Hu Q. [82]	Teachers' Perceptions Of Teaching Sustainable Artificial Intelligence: A Design Frame Perspective	Sustainability (Switzerland)	They studied 18 experienced teachers, their AI teaching perspectives, and effective instructional designs using interviews and observations.	Effective AI instruction: tackle barriers, use design thinking, enhance teacher knowledge, stress social impact, and holistic understanding.

Authors	Title	Source Title	Methodology	Findings
Cheah Y.H.; Chai C.S.; Toh Y. [83]	Traversing The Context Of Professional Learning Communities: Development And Implementation Of Technological Pedagogical Content Knowledge Of A Primary Science Teacher	Research In Science And Technological Education	Cultural, historical activity theory framed a case study examining interactions within and between two professional learning communities. It aimed to understand the alignment and misalignment dynamics between these activity systems.	Research reveals Sean's educational challenges shifting from collaborative to internal school learning communities, hindering TPACK growth. Issues include tool use, disruptions, and leadership support, emphasizing the need for better organizational design.

4. Discussions and Conclusion

Considering the outcomes and discoveries, these three principal motifs offer valuable insights and illumination regarding the efficacy of design thinking as a potent pedagogical paradigm suitable for integration within K-12 educational settings. It is imperative to recognize this approach's promising potential, as it can exert a constructive influence on the empowerment of students, educators, and stakeholders, ultimately facilitating the adoption of this approach in educational technology. This, in turn, opens avenues for modernized teaching and learning approaches customized to meet the requirements of the 21st century.

The first theme explored in this compilation of articles focuses on Design Thinking in education, particularly within K-12 settings, with the objective of encouraging stakeholders to embrace this methodology in educational technology. Several studies contribute to this theme. For example, Kijima and Sun [17] highlighted the need to surf into the design thinking potential to engage female youths in STEAM fields. Ladachart *et al.,* [55] discovered that students became more comfortable solving engineering problems through design thinking, while Harris [56] employed Design Thinking to enhance Information and Communication Technology (ICT) use in early childhood English as a Second Language (ESL) education. Wu *et al.,* [61] demonstrated positive outcomes in students' design thinking through Chinese wooden arch bridge culture exposure. Researchers have studied the effect of design thinking in educational technology as Tramonti *et al.,* [57] introduce a methodological framework combining Design Thinking with Educational Robotics in secondary schools. Ozturk and Korkut [51] advocate for structured STEM activity design within a Design Thinking framework in another study. In another research, Videnovik *et al.,* [59] assessed a case study on integrating games into education using Design Thinking. At the same time, Elwood and Jordan [60] emphasize the importance of Design Thinking models for teacher-driven instructional design. Lastly, Arbieto-Batallanos *et al.,*[2] propose a user-friendly mobile application for teaching kinematics using Design Thinking, supported by positive student feedback. Moreover, Liu *et al.,* [62] talked about how incorporating the Stanford DT model into a technological literacy course had a positive effect on boosting creative self-confidence, innovative problem-solving abilities as well as motivation related to technology among pre-service teachers. These articles collectively underscore the multifaceted potential of Design Thinking in reshaping educational paradigms. They illuminate its capacity to serve as a catalyst for innovative pedagogical approaches, elevate STEM education by fostering creative problem-solving, empower educators in the instructional design process, cultivate interest in STEAM domains, and optimize ESL instruction through technology integration. Additionally, they emphasize the significance of adopting user-centric design thinking methodologies to craft impactful educational solutions. However, it is essential to acknowledge the ongoing evolution and adaptation required to fully harness the transformative power of Design Thinking in education. While these studies highlight its versatility and promise, ongoing research and critical evaluation are imperative to ensure seamless integration into diverse educational contexts.

In our second theme, we explore a collection of articles that collectively dive deep into the concept of Student-Centered Learning Environments. These articles share a common goal of integrating a user-friendly Design Thinking approach into the realm of educational technology. Rooted in qualitative paradigms and descriptive studies, these works employ Design Thinking models to analyze participant responses. A study by Valentim *et al.,* [56] revealed the significance of adaptable teaching strategies, flexible schedules, and open, supportive teacher-student dynamics in shaping an ideal school day by using design thinking as methodology. Design Thinking

was used by Shipepe *et al.,* [64] to research highlighting the potential application of this approach in primary school classrooms to empower students in computational and design thinking, transforming them into creators of Fourth Industrial Revolution technologies. Additionally, Tsortanidou *et al.,* [65] and Motschnig *et al.,* [66] emphasize the necessity of nurturing digital competencies alongside personal and social skills over time, involving teachers to enhance sustainability and facilitate cross-border educational innovations. Furthermore, Jovanovic *et al.,* [67] found that incorporating autonomous robots in education is an effective means of imparting STEM concepts through hands-on engagement and design thinking principles. The Lamp&d project demonstrates the collaborative development of design thinking through problem-based learning and playful methodologies, showcasing the potential of digital fabrication technologies and prototyping [68]. Lastly, the integration of robotics and digital storytelling in education is explored, revealing enhanced student engagement, design thinking application, and the development of 21st-century competencies [3]. Moreover, Herron and Wolfe [69] discussed the establishment of professional development offerings for K-12 educators as well as leaders, aligning with educational technology standards and emphasizing practitioner-faculty roles in facilitating digital transformation programs. These studies underscore the importance of student-centric approaches, adaptability, and interdisciplinary engagement in modern educational environments. In conclusion, the research showcased here signifies a paradigm shift towards more dynamic, student-centered learning environments guided by Design Thinking principles. These findings stress the need for flexibility, digital competencies, and collaborative teaching practices to shape the ideal school day and prepare students for an increasingly complex educational landscape.

This compilation of the article's third theme discusses various aspects of innovative educational technology and design thinking in education. It begins by emphasizing the importance of innovative teaching methods to prepare students for the information society. For example, Segura *et al.,* [70] present a project focused on implementing a Virtual Learning Environment in Andalusia, Spain, to optimize educational resources and align with the EU's Digital Education Action Plan. Another study by Phumphongkhochasorn [71] elaborates the utilization of design thinking as well as reflection to promote competence in teaching. Additionally, Churchill [73] stressed that using design thinking for digital storytelling using mobile technologies is shown to enhance students' digital literacy skills. A framework for supporting design thinking in Collective Intelligence educational technologies is introduced, emphasizing its potential to develop advanced human capabilities [74]. The impact of gaming platforms, like Discord, on institutional spaces and expectations is explored, along with the significance of digital fabrication and design thinking in developing students' understanding of technology [75], [76]. Furthermore, intersectionality research and design thinking are combined to create intersectional design concepts [77]. Lastly, a mobile application for teaching physics through sensors, grounded in design thinking, can potentially encourage innovation in pedagogy [81]. Most researchers address the challenges of teaching artificial intelligence in schools and the importance of organizational design thinking for teacher development in pedagogical endeavors [72], [78]–[80], [82], [83]. These articles collectively contribute to the evolving landscape of innovative educational technology and design thinking in education.

In summary, integrating Design Thinking as a fundamental approach for product design within the educational context can provide substantial benefits to all involved stakeholders, particularly educators and students, by enhancing their proficiency in educational technology. Given the ever-evolving nature of the educational sector, the integration of design thinking principles can catalyze promoting competitiveness, technological aptitude, and innovation within K-12 classrooms. This, in

turn, contributes to the advancement and enduring sustainability of further research towards 21st-century education [84].

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