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Systematic Comprehensive Review of Circular Economy Integration for Vocational Learning

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ABSTRACT

The achievement of current Sustainable Development Goal (SDG) in an increasingly complex global society drives the need to integrate circular economy principles in vocational education. Therefore, this study seeks to examine the use of the circular economy concept in the context of vocational learning. The identified problem is the lack of in-depth understanding of how the circular economy can be effectively integrated in vocational learning programs. The lack of complete and systematic information sources in this area is another issue that needs to be resolved. The objective of the study is to identify the potential integration of the circular economy in vocational learning. This study aims to conduct a comprehensive systematic review on the integration of the circular economy in vocational learning. In this study, we used the PRISMA approach to find primary data based on several keywords such as "circular economy", "vocational education", and "sustainability learning". Based on advanced searching on Scopus, Web of Science and Directory of Open Access Journals (DOAJ) we found n=23 relevant articles for this study. The experts have identified three main themes; (1) Circular Economy Concepts and Implementation; (2): Circular Economy in Industry; and (3): Circular Economy Benefit. In conclusion, this study provides a comprehensive view on the integration of the circular economy in vocational learning. The results of this study are expected to provide guidance to educators, researchers, and stakeholders in their efforts to strengthen sustainability-oriented vocational learning. In addition, the results of this study also provide a basis for further research in this field, which is important to strengthen the awareness and implementation of the circular economy in vocational education for a more sustainable future.

Keywords:
Systematic review; circular economy; vocational learning

1. Introduction

In our rapidly changing global landscape, the concept of a circular economy has emerged as a beacon of hope, offering a potential solution to pressing challenges [1-3]. This innovative economic system aims to minimize waste and optimize resource usage through practices like recycling, reusing, and remanufacturing [4-6]. Integrating circular economy principles into education, especially vocational learning, is pivotal for instilling a sustainable mindset in upcoming generations [7].

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Vocational education equips individuals with the vital skills [8-10] and knowledge needed to contribute meaningfully to a sustainable and circular economy [11].

Ultimately, this integration has the potential to empower individuals with the expertise required to actively participate in creating a more sustainable and circular economic landscape [12]. By fostering innovation and problem-solving within the circular framework, vocational education emerges as a pivotal force in propelling the transition towards a sustainable future [13-15]. The objective of the study is to identify the potential integration of the circular economy in vocational learning. The research question is to what extent circular economy can be integrated in vocational learning?

2. Literature Review

The circular economy (CE) is crucial in tackling resource sustainability and waste issues. In Vietnam, integrating CE into STEM education is promising. A study with 873 secondary school teachers highlights strong support for CE in STEM teaching. This underscores the significance of educating the youth about CE for long-term sustainability aligned with SDGs like SDG4 and SDG 12.5 [16]. This is also supported by [17] who studied the involvement of teachers in the creation of teaching strategies. His study found that the education system in Finland supports the introduction of circular economy teaching to school students. Education is important for sustainable development that instils awareness and values for the transition to a circular economy in Ukraine [18]. An online survey revealed gaps in circular economy understanding and appreciation for local ecology, highlighting pressing economic and environmental concerns. The goal of fundamental educational principle and the circularity idea are completely compatible as depicted in Figure 1 [19].

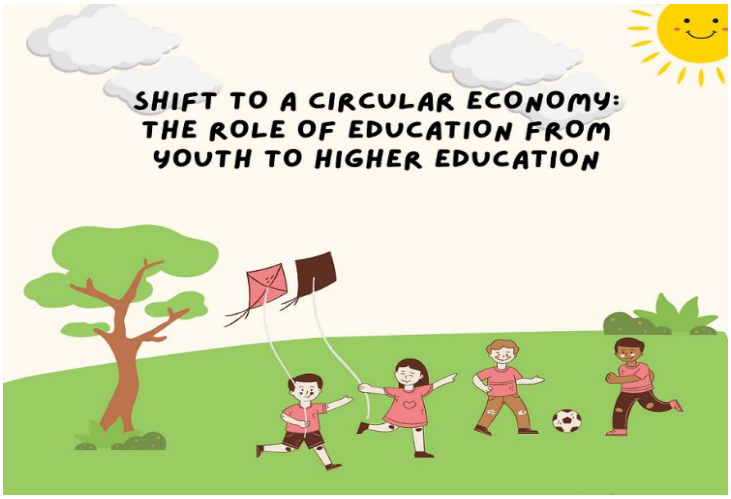

Fig. 1. Picture adapted from Piyush Dhawan *et al.,* [19]

The importance of digital tools in circular economy teaching, especially asynchronous courses, shows the success of its use. Case studies show that modern e-learning with hands-on methods such as the Erasmus+ Project improves teachers' digital pedagogical skills [20]. In the context of higher education institutions (HEIs), a study on circular economy and the relevance of Circular Economy in HEIs shows how HEIs can take advantage of existing resources to practice CE [21], examine the use of existing CE tools in HEIs [22], and how higher education institutions can use sustainable development theory in planning CE programs [23]. The results of the study provided an application framework involving CE

practices, CE measurement tools used in HEIs, and the need to adapt existing CE tools to better fit the context of HEIs [21,22]. Meanwhile, sustainable development theory can be applied to create CE resources for communities, necessitating tailored educational strategies in HEIs [23].

The development of a business model based on CE leads to challenges in interior design through rethinking interior design for sustainability, emphasizing the ecosystem concept based on the 10 R's in retail design [24]. This highlights the importance of sustainable design concepts that are relevant for education. The University of Cape Town case study revealed that the role of green technology in improving water and energy management, promoting resource efficiency and advancing circular economy practices to achieve net-zero carbon goals [25]. The convergence of the fields of circular economy, bioenergy, education and communication suggests potential research for the Sustainable Development Goals [26]. Educational reform is essential for the transition to a circular economy, especially in design and engineering. Distinguishing between recycling and upcycling is important for teaching sustainable practices, offering clear guidance for future designers and engineers [27].

2. Methodology

2.1 Identification

The systematic review process consists of three basic phases that were used to choose many relevant papers for this study. The first phase entails the identification of keywords and the search for associated, related terms using thesaurus, dictionaries, encyclopaedias, and prior research. Following the selection of all pertinent keywords, search strings for the databases Scopus, World of Science (WoS), and Directory of Open Access Journals (DOAJ) (see Table 1) have been developed. The current research endeavour was effective in successfully retrieving 1615 papers from all databases throughout the first stage of the systematic review process.

Table 1
The search string in identification phase

Database	Search string
Scopus	TITLE-ABS-KEY ("Circular Economy" AND (vocational OR technical) AND (education OR study OR learn*)) AND PUBYEAR = 2023 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) Access date: 17 September 2023
DOAJ	"Circular Economy" AND (vocational OR technical) AND (education OR study OR learn*) Access date: 17 September 2023
WOS	"Circular Economy" AND (vocational OR technical) AND (education OR study OR learn*) Access date: 17 September 2023

2.2 Screening

Based on a number of inclusion and exclusion criteria created by academics, 1385 papers were excluded in the first screening phase, while 86 duplicate articles were removed in the second. Because literature (research articles) is the main source of useful knowledge, it was the first criterion. Additionally, publications in the form of systematic reviews, reviews, meta-analyses, meta-synthesis, book series, books, chapters, and conference proceedings are excluded from the current study.

Additionally, the review was limited to publications that were published in 2023 and were written in English. A total of 121 publications were eliminated based on particular criteria.

2.3 Eligibility

The third level, called eligibility, has a total of 144 items ready. At this point, all article titles and important content were carefully examined to make sure they met the criteria for inclusion and complemented the current study's objectives. Consequently, 121 publications were excluded since they did not constitute pure science articles supported by actual data. 23 articles are available for review as of this writing (see Table 2).

Table 2
The selection criterion in searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2023	< 2023
Literature type	Journal (article)	Conference, book, review
Publication stage	Final	In Press

2.4 Data Abstraction and Analysis

In this study, a number of research designs (quantitative, qualitative, and mixed techniques) were examined and synthesized using an integrative analysis as one of the assessment strategies. The competent study's objective was to determine pertinent subjects and subtopics. Data collection was the initial phase of the theme's development. Figure 2 demonstrates how the authors painstakingly examined a collection of 23 articles for claims or content pertinent to the subjects of the current investigation. The authors then assessed recent noteworthy studies on circular economy for vocational learning. Studies are being conducted into both the research findings and methods employed in all studies [28,29]. The author then worked with other co-authors to create themes based on the data in the context of this study. Throughout the data analysis process, a log was kept to note any analyses, opinions, puzzles, or other ideas that might be pertinent to the data interpretation [30-33]. The writers then compared the findings to look for any discrepancies in the theme design procedure. It is important to note that the writers discuss any differences in the concepts among themselves if there are any. Final adjustments were made to the themes created to guarantee uniformity. Two experts, one in vocational learning (Fathiyah Kamaruzaman—expert in vocational and technical education) and the other in the circular economy (Mohamad Sattar Rasul—expert in sustainability), carried out the analysis selection to ascertain the legitimacy of the issues. By confirming the domain validity, the expert review process makes sure that each subtheme is clear, significant, and appropriate.

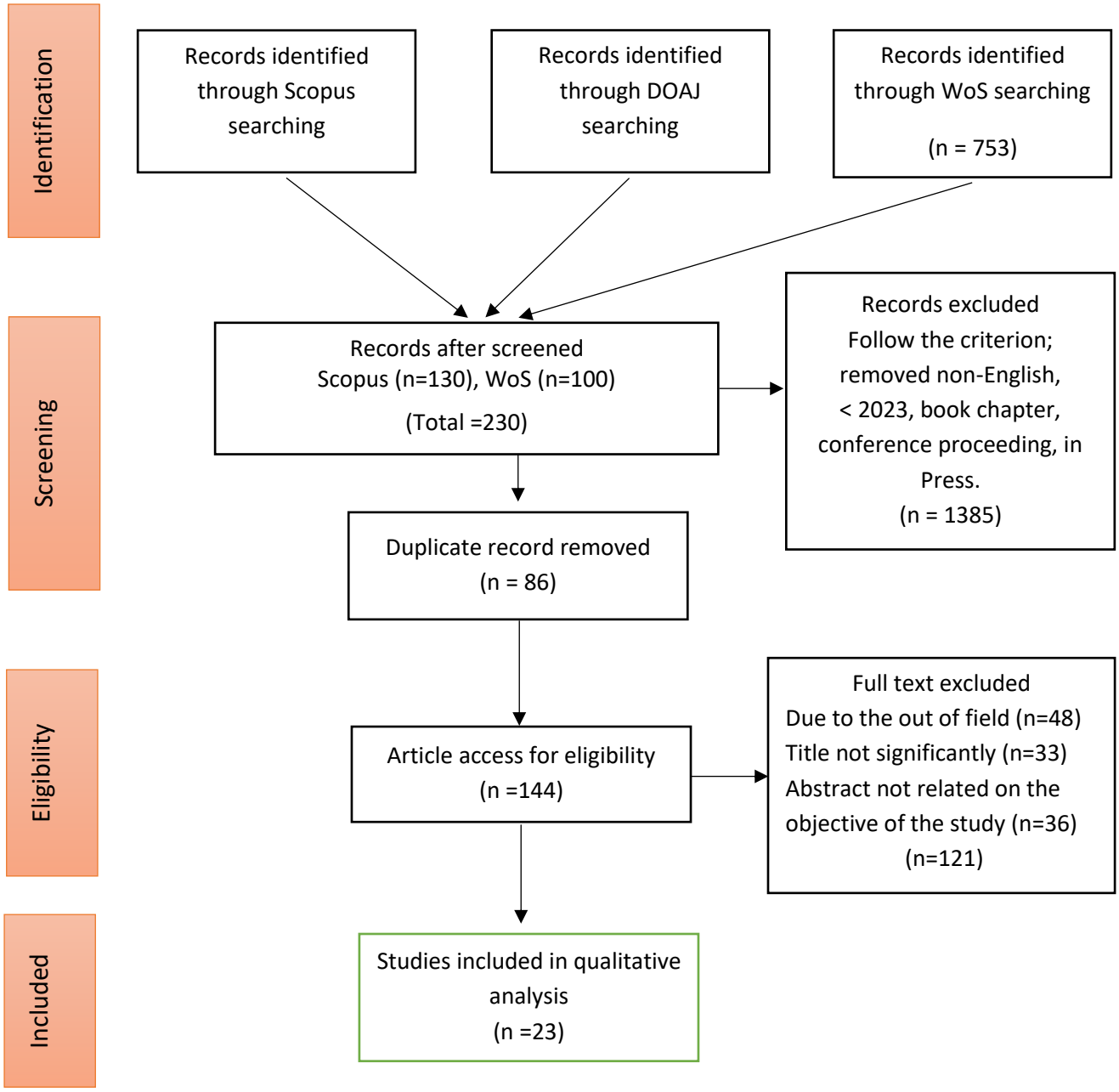

Fig. 2. Flow diagram of the proposed searching study [34]

3. Result and Finding

To implement the circular economy in education, the articles that have been selected are categorized into 3 themes which is; (1) Circular Economy Concepts and Implementation; (2): Circular Economy in Industry; and (3): Circular Economy Benefit.

3.1 Theme 1: Circular Economy Concepts and Implementation

There are eleven articles in this theme. Table 3 is the summary of the article.

Table 3
Theme 1: Circular Economy Concepts and Implementation

	Source	Methodology	Results
1	Chen *et al.,* (2023) [35]	The study uses partial least squares structural equation modeling to analyze data from an online survey of 285 employees from 457 European businesses.	According to the report, sustainable supply chain management, supply chain design, and technical improvements all have a favorable impact on life cycle assessment and circular economy capabilities.
2	Galvão *et al.,* (2023) [36]	This research utilized survey-based data to validate a structural and measurement model using partial least squares structural equation modeling.	The research model fills a vacuum in quantitative studies on the circular economy by validating value flow via technical cycles, emphasizing the impact of competitive factors on value stream, and highlighting this impact.
3	Guarnieri *et al.,* (2023) [37]	A questionnaire that took into account the technical, social, environmental, and economic aspects rated 24 circular economy strategies using a five-level ordinal scale.	The survey is regarded as a credible and accurate method for examining the circular economy priorities of nations, regions, and cities.
4	Husgafvel & Sakaguchi (2023) [38]	A questionnaire survey was used in the study to evaluate the present and potential future condition of CE development in the wood building industry.	Some respondents are unaware of the importance of CE in wood building, which includes sustainability, long life cycles, co-creation, training, and competence development.
5	Jayawardane *et al.,* (2023) [39]	The study evaluates the technical performance, environmental effects, and life cycle costs of 3D printing a centrifugal semi-open pump impeller using recycled PLA material.	The study found that the use of recycled material in additive manufacturing decreases tensile strength, fatigue strength, density, and hardness.
6	Julkovski *et al.,* (2023) [40]	Through document analysis, technical visits, and in-person interviews with 11 Brazilian and 11 Portuguese businesses, a qualitative study was carried out.	The report reveals disparities in technological and innovative maturity, circular economy development, and recycling procedures between Brazilian and Portuguese enterprises.
7	Kazancoglu *et al.,* (2023) [41]	The circular food packaging design is evaluated in terms of 29 customer expectations and 34 technical requirements using the Quality Function Deployment approach.	The main consumer expectations are listed, and a relationship between them and the technological needs is shown.
8	Keramitsoglou *et al.,* (2023) [42]	The study suggests integrating the CE vision into school curriculums, promoting creative teaching methods, and offering practical educational strategies.	Students advocate for the inclusion of theoretical instruction in experiential learning to enhance understanding of abstract concepts like sustainability and the positive impacts of circular enterprise implementation.
9	Reike *et al.,* (2023) [43]	The Netherlands aims to achieve 100% circularity in textiles by 2050, requiring a thorough study of the transition processes and elements that support and hinder this goal.	The study recommends Extended Producer Responsibility as a feasible intervention for system change, focusing on secondhand, mechanical, and chemical recycling for technological advancement.
10	Skripnuk *et al.,* (2023) [44]	The methodology for creating a circular economy in a region involves a zero-waste program, subprograms, Industry 4.0 technologies and various methodologies.	The study explores garbage classification in a municipal area, focusing on recycling polymer materials, using a mathematical model to guide decision-makers in choosing the best program.
11	Ziegler *et al.,* (2023) [45]	The research is based on a survey of 165 cooperatives in Québec, Canada, and an exploratory database.	Cooperatives are crucial for the circular economy as they encourage reuse, recycling, production rethinking, sharing, and durable usage, potentially integrating it into local economies and cultures.

3.2 Theme 2: Circular Economy in Industry

There are six articles in this theme. Table 4 is the summary of the articles.

Table 4
Theme 2: Circular economy in industry

	Source	Methodology	Results
1	Adamides (2023) [46]	This article employs a case study methodology to assess the "fitness" of a conceptual perspective.	Music streaming and the transition of the olive oil-producing industry towards a circular economy using cutting-edge waste-processing technology are both understood using activity theory.
2	Akyazi *et al.,* (2023) [47]	In six energy-intensive European sectors, this study outlines the most important skill sets needed for Information Systems and Electronics (IS and EE).	This research is designed to serve as a model for academic and industry training programs that will provide the necessary skills.
3	Antwi-Afari *et al.,* (2023) [48]	The study evaluated the environmental, technical, functional, and system dimensions of a modular steel slab in a Chinese residential construction using the LCA system boundary and predictive building systemic circularity indicator.	A case slab's bulk might be recycled to the extent of 50.4% in the base scenario, compared to 0%, 70.8%, and 38.8% in the other scenarios. The baseline scenario had a global warming potential of 38.64 kg CO2/m2. Adopting the best course of action should have favorable effects and high recoverability.
4	Dastane *et al.,* (2023) [49]	The study uses ATLAS.ti 9 software and the Netnography technique to examine 13,147 user-generated reviews posted on the Google Play Store after using the best free education applications.	Technical, content, pedagogical, gamification, and learning value are among the study's primary context-specific CPV dimensions, from which it pulls subdimensions and items.
5	Wrålsen & O'Born (2023) [50]	Two Norwegian companies' primary data is used to evaluate circular economy business models, compare second life battery scenarios, and propose a consequential LCA procedure for battery life cycle assessments.	The study highlights the importance of life cycle evaluation in circular economy business models, emphasizing the need to reduce manufacturing emissions in battery value chains.
6	Yoshino *et al.,* (2023) [51]	The EU's national innovation system (NIS) framework was used to assess proactive-EI determinants among SMEs using a multilevel framework, analyzing data from 6,188 resource-intensive sectors.	Public awareness, economic complexity, and public sector R&D positively influence SMEs' adoption of proactive-EIs, while sectoral agglomeration and external collaboration negatively impact green entrepreneurship in developed economies.

3.3 Theme 3: Circular Economy Benefit

There are six articles in this theme. Table 5 is the summary of the articles.

Table 5
Theme 3: Circular Economy Benefit

	Source	Method	Results
1	Balaji *et al*., (2023) [52]	The study focused on social, structural, and Circular Economy variables while assessing the drivers of farm success utilizing a two-step methodology and survey data.	According to the study, societal structural barriers have a negative influence on farm efficiency while farmers' control over CE strategies has a positive effect. Access to inputs can maximize the yield of natural resources.
2	Cheffi *et al.,* (2023) [53]	Using survey data and structural equation modeling, this study investigates how ethical leadership and management control systems affect the circular economy in 111 small and medium-sized businesses in the UAE.	The study finds that management control systems and ethical leadership have a beneficial influence on small and medium businesses' adoption of circular economy techniques.
3	Farrukh *et al.,* (2023) [54]	The study examines waste reduction, pollution reduction, resource rotation, and environmental conservation strategies employed by the New Zealand FP industry, indicating their contribution to the circular economy.	The report emphasizes how crucial external, strategic, technical, and human resource players are to advancing the circular economy through the implementation of GLSS in the process industry.
4	Kadhila *et al.,* (2023) [55]	The study used a mixed-methods approach, integrating structured interviews, document analyses, and direct observation with quantitative and qualitative data collection techniques.	The study reveals that Langebaan and Swakopmund municipalities face challenges in integrating the circular economy into their waste management systems, potentially leading to sustainable practices.
5	Moradnezhadi *et al.,* (2023) [56]	A study used the theory of planned behavior and PLS SEM to examine the intents and actions of 500 farmers in these systems toward the circular economy.	The study reveals that farmers' attitudes, norms, and behavioral controls significantly influence their willingness to utilize water recycling in rice and fish farming systems.
6	Singh *et al.,* (2023) [57]	The qualitative exploratory approach highlights the intricate link between travel and tourism, highlighting the potential of implementing circular economy concepts to enhance a robust tourism environment.	The study highlights challenges faced by managers, decision-makers, and organizations in transitioning the tourism industry to a circular economy, emphasizing the need for further research in education, technical knowledge, and engineering.

4. Discussion

Recent research provides significant insight into the circular economy. The positive influence of sustainable supply chain management [58] and value flow in the technical cycle give weight to the competitive factor [59]. A survey in assessing the priorities of the circular economy gives credibility [37]. Meanwhile, a gap of awareness in the use of wood in circular principles was identified [38]. Additive manufacturing on recycled materials shows circular economy is very beneficial [39]. Circular development between Brazilian and Portuguese enterprises reveals differences [40]. Consumer demands are linked with technology needs sheds light on an important dynamic [41]. Integrating theoretical and experiential learning for a deep understanding of sustainability is essential [42]. Supporting chemical recycling in systemic solutions offers a strategic route [43], developed a zero-waste model for recycling polymeric materials [44]. Finally, cooperatives play an important role in advancing circular practices [60]. Collectively, this study enriches our understanding of the circular economy concept and its implementation.

The transition of the olive oil industry to a circular economy using activity theory and advanced waste processing [61] extends this research to design a comprehensive training program [47]. Waste recycling in the concrete industry has an impact on global warming potential [48]. Critical dimensions in Curriculum Value Assessment have been identified [49] In order to highlight the transformative potential of life cycle assessment, especially in battery recycling [50], important factors influencing the adoption of Green Innovation among SMEs are introduced [51]. Their findings contribute significantly to the understanding of the circular economy in industry. Community barriers influence farm efficiency, emphasizing the positive impact of farmer control over CE strategy [52]. The management control system and ethical leadership proved to be influential in the use of the circular economy of SMEs [53]. Farrukh *et al.,* [54] underlined the importance of external players in advancing the circular economy through the implementation of GLSS in the process industry. The study revealed the challenges faced by Langebaan and Swakopmund municipalities in fully embracing the circular economy concept in waste management, emphasizing the potential for knowledge development in sustainable practices [55]. Furthermore, farmers' attitudes and norms influence their use of water recycling, highlighting the need for circular economy solutions [56]. Thus, underlines the complexities faced by managers and decision makers in the transition of the tourism industry to a circular economy, emphasizing the need for further research in education, technical knowledge and engineering [57].

5. Conclusions

In conclusion, this systematic comprehensive review underlines the critical role of integrating circular economy principles in vocational learning. The analysis of 23 articles resulted in three themes: Concept and Implementation of Circular Economy, Circular Economy in Industry and Benefits of Circular Economy. This indicates that the circular economy has the potential to be integrated in vocational learning. The themes identified provide valuable insights for educators, researchers and stakeholders on the integration aspects of the circular economy. This study also serves as a basis for further research in the field, emphasizing the need to strengthen the awareness and implementation of the circular economy concept in vocational education to meet the demands of the growing global economy.

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