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ICT Enabled TVET Education: A Systematic Literature Review

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ABSTRACT Economies of the world and workforce level of skills are changing rapidly. Industrial revaluations and knowledge economies have raised the demand for a knowledgeable and digitally equipped skilled workforce. Technical and Vocational Education and Training (TVET) is an educational stream that provides vocational skills to youth and produces a skilled workforce for the industry. The role of Information and Communication Technologies (ICT) in the TVET pedagogy, training delivery, teachers training, curriculum, and labs is need of the day to meet current era challenges. In the TVET education training cycle, the level of ICT enablement is required to be reviewed. This Systematic Literature Review (SLR) evaluates literature for innovation of ICT in TVET education for the last ten years. This study aims to identify and present ICT-based technology innovations, research, and applications used in TVET training cycle system components/functional areas to identify gaps for future research directions/agenda. This gap identification will help (i) TVET training institutes to upgrade their teachers, curriculum, labs and, equipment, (ii) policymakers to devise technology-oriented skilled workforce development policies, (iii) to provide guidelines to industry, researchers, and academics to focus on gaps to address future challenges of workforce development. Based on the search string, we found 2,445 relevant documents and after applying quality assurance and inclusion/exclusion criteria, finally, 134 documents were selected for the study and analyzed. The result of this systematic literature review identifies that ICT technologies and application dispersion into TVET training cycle system components/functional areas is very low particularly in monitoring and evaluation, career guidance and job placement, trainee's assessment, and teacher's training. TVET Technology index suggests that much focus is needed on IoT, Robotics, Data Science, Artificial intelligence, cloud computing, and other similar technology induction to all TVET training.

INDEX TERMS ICT enabled TVET, TVET systems, TVET systematic literature review.

I. INTRODUCTION

TVET is an educational program that focuses on learning through formal/informal training to produce the skilled workforce required for industries [1]. The economy and world of skills are dynamic factors in the current era as many jobs that existed a couple of years ago are no longer available today. The changing needs of the knowledge economy and the influence of technology have changed the demand for higher-level skills in the industry [2]. The industrial 4.0 revolution has enabled industries to adopt smart manufacturing and to digitally transform themselves [3]. 65% of children who are currently enrolled in primary school today will ultimately work on jobs that don't exist today [2]. Many skilled workforce roles don't exist today which have been changed due to obsolete products and upgradations of manufacturing using ICT. World Economic Forum 2020 [4] estimates that in the next decade skilled jobs will shift towards artificial intelligence, data science, robotics, DevOps, cloud computing, and social media, etc. All these challenges demand the evaluation of existing skilled TVET training infrastructure to meet the upcoming challenges.

ICT is a broader spectrum that includes all communication technologies, software, video conferencing, social media, and other digital media to use, store, transmit, and manipulate information digitally [5]. The role of ICT in TVET needs to be increased as it is effectively being used in higher education and school education [6]. United Nations (UN) sustainable

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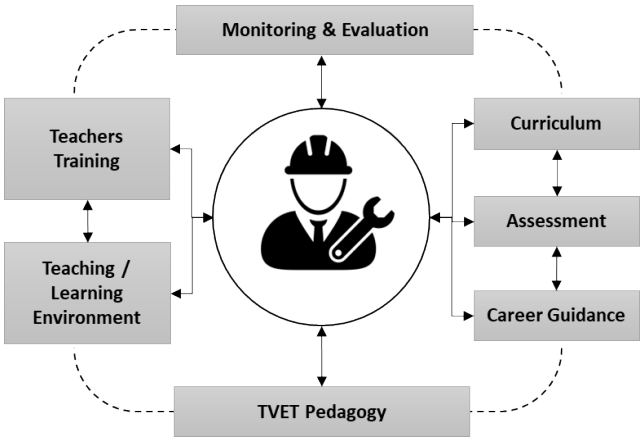

FIGURE 1. TVET training cycle major system components/functional areas.

development goals 4.3 and 4.4 for the year 2030 is a target to emphasize poverty alleviation [7]. TVET plays an important role in sustainable development and poverty alleviation.

To evaluate the effective integration of ICT in TVET, the TVET training cycle can be linked with seven (07) major system components/functional areas. Figure 1 shows the details of these components/functional areas. As shown, the cycle starts from the curriculum cycle. The curriculum system includes TVET qualification frameworks development, courses skills inventory, training hours (theoretical & practical), training manuals for trainees, and training lesson plans for instructional staff. The assessment components include TVET qualification awarding body details, trainee certification, competency-based training, and sessional (during training) internal and external assessments. Career guidance includes TVET employment opportunities, industry details, employers profiles, and guidelines for TVET trainees to access, apply and get a job in the industry or switch on entrepreneurship to start their own small business. TVET pedagogy component includes TVET general training practices and all other general TVET areas which cannot be classified in any other component. The teaching/learning environment includes TVET course delivery for theory and practical labs, classroom environment, learning gadgets, and learning tools and equipment. The teacher's training component is related to a teacher's skills enhancement and pedagogy training. Finally, Monitoring and Evaluation (M&E) is a component which evaluates, monitor, and controls the overall TVET programs efficiency, effectiveness, and management. M&E works on basis of Key Performance Indicators (KPI) definition, monitoring, and control. These KPIs help us to gauge the overall performance of the TVET system. M&E evaluates the TVET program's output and outcome. TVET output is the quality of TVET graduates and TVET outcome is the cost-benefit analysis of TVET training investments by the Government/donors/ funding agencies.

In Pakistan, the TVET target audience comprises normally young boys and girls who are living below the poverty line [8]. The majority of this youth is either school dropouts or belongs to the class who cannot afford to continue their education due to poverty or lack of opportunities. Since Pakistan's 60% population [9] consisting of youth thus our motivation to conduct this study is to evaluate the current level of ICT enablement in TVET education to find gaps and propose future research agenda and guidelines for TVET training providers, policymakers, industry, academia, funding agencies/donors and researchers. State of art concludes that this is the first of its kind study thus it has a global impact too.

The remaining of this paper is organized as follows: Section II includes the state of the art work carried out on the topic, section III includes materials and methods. Material and methods are further alienated into five subsections. These five subsections include (3.1) research questions and their motivation, (3.2) search strategy including searching terms, literature source and search procedure, (3.3) study selection, (3.4) data extraction, and (3.5) systematic review execution. Section IV includes the results and findings and section V elaborate the Quality Evaluation of this study. Section VI identifies Limitations of this SLR, finally, section VII conclusion and future work are divided into three subsections; (6.1) Conclusion, (6.2) Research Contribution, and (6.3) Protentional Areas for Future Research for TVET training providers, policymakers, industry, Governments, donors, funding agencies, academia, and researchers.

II. STATE OF THE ART

This is quantitative research to explore the current ICT enablement level into the TVET education in the six research dimensions. These six dimensions include; (i) major ICT enabled TVET education research publication channels, (ii) ICT software tools/applications used in TVET, (iii) Empirical and research type focused in TVET, (iv) specific industries focused in TVET, (v) TVET training cycle components focused and finally (vi) teaching-learning environment used in TVET ICT enablement. To the best of our knowledge after studying numerous literature reviews, no other SLRs focusing on ICT enabled TVET education with dimensions to ICT technology explored, industry referred, Teaching/Learning environment focused and, TVET training cycle system components/functional areas is found. However, there are some reviews, survey, and guidelines which partially discuss the generic role of ICT in TVET with the dimensions of TVET teachers training, TVET classrooms, and ICT experiments with different software tools and Learning Management Systems (LMS) in TVET. This study aims to address this gap present the current research status on the above six dimensions and suggest future research agenda and guidelines for TVET training providers, TVET policymakers, industry, academia, and researchers.

Four studies, research, and reports related to ICT and TVET have been found in the literature review. This review, survey, and guidelines can be overlapped with the objective of the current broader study. These limited studies have been discussed with a focus that how identified limitations/gaps

can be used to bridge the gap in the scope of the current systematic literature review.

Firstly, a study of Portugal [10] for the period between the years 2000 to 2015 is carried out on the open-access reporting scientific library of Portugal's Ph.D. thesis & master dissertation. This study aims to identify the thesis and dissertation which focuses on distance learning in TVET education in Portugal. Among the relevant 13 Ph.D. thesis and 151 Master dissertations, 60 studies were selected. The study concludes that distance education for TVET in Portugal is a growing interest but it is not being focused on the national level. Distance education in TVET is recommended to be practiced and it needs to be focused on using ICT technology. This is a limited study focusing on only one country, one library, and one teaching-learning technique of ''Distance Learning. We have expanded this research by focusing on ICT-enabled TVET education globally, searched literature from renowned and authentic libraries, and used maximum available teaching-learning environments.

Secondly, a systematic review for ICT integration in TVET [11] through 20 selected research publications for years between 2003 – 2014 is carried out. This study is carried out with four objectives; (i) review ICT integration into TVET classroom teaching and learning environment, (ii) to understand usage of ICT applications in TVET classrooms and, (iii) ICT integration into three learning modes of fully mediated (distance), partially mediated (blended) and supplementary. The result of this study reveals that acceptance of ICT integration in TVET is very less as compared to higher education and school education. 57% of learning modes being used ICT in TVET are fully mediated, TVET teaching-learning environment is using 5% standard, and 95% customized application as a tool in TVET classrooms. Learning outcomes of the study are mostly focusing on the cognitive learning domain and very little on psychomotor. This study was carried out 7 years ago with the focus on TVET ICT integration into classrooms and the teaching-learning environment. We have expanded this research with the latest literature and focused not only on classrooms and teaching-learning environment but also on TVET curriculum, trainee's assessment, teachers training, monitoring, and evaluation.

Thirdly, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and Commonwealth of Learning (COL) published a book [12] with the title ''Using ICT and Blended Learning for transformation TVET''. This book evaluates and proposes ICT in TVET transformation using distance education, open learning, blended learning, open educational resources, and open courseware, massive open online courses, virtual reality/augmented reality, etc. using ICT-based applications. Various countries' ICT-enabled TVET case studies have also been discussed in the book. This book was published in the year 2017 and provides wide guidelines for ICT and blended learning in teaching. We have used these guidelines to form the basis of our RQ6 and explore the dimension of teaching-learning environment used and technology-focused in ICT-enabled TVET education.

Lastly, an online conference [13] with the title ''ICT for TVET'' was organized by UNESCO which was held in Germany in the year 2013. This conference focuses on challenges and goals for introducing ICT base initiatives in TVET education. We have used the recommendations and guidelines of this conference to improve our SLR. The majority of the guidelines are related to TVET pedagogy like (i) guidelines for ICT as tools to increase the reach and impact of TVET through ICT, and (ii) ICT's in the classroom: how can ICT be used in classrooms to improve learning outcomes, etc. Beyond the above four limited studies, no other study is found in the selected libraries/databases.

III. MATERIAL AND METHODS

This SLR is conducted following PRISMA and Kitchenham, Charters, and Mendes guidelines [14]–[16]. In this section, we systematically describe the process through which this SLR is accomplished. We enumerate the research questions and conducted this study to get answers to raised questions. This section has five subsections. Section 3.1 ''Research Questions'' explains 6 raised research questions and their motivations. Section 3.2 ''Search Strategy'' elaborates search terms used to extracted relevant literature, selected literature sources/libraries, and explains the carried literature search procedure. Section 3.3 ''Study Selection'' contains inclusion/exclusion criteria followed in the final study selection. Section 3.4 ''Data Extraction'' recapitulates the study documentation and quality assurance process. Finally, section 3.5 ''Systematic Review Execution'' summarizes the search execution, data collection, and data selection process. Results of the entire study execution are shown in section IV under ''Results''.

A. RESEARCH QUESTIONS

In this research, we want to focus on ICT-enabled TVET education particularly with the dimensions of publication sources, industry-focused, ICT technology-focused, and TVET training cycle addressed. Therefore, the following research 6 questions have been raised to evaluate existing literature to find the current level of research and gaps.

RQ1. Which are major research publication channels for ICT-enabled TVET education?

The main motivation behind this question is to understand ICT-enabled TVET education research publication libraries, channels (like the conference, journal, symposium, book, etc.) publication country, and publication years.

RQ2. Which ICT technology/functional areas have been focused to improve TVET training?

This question aims to identify ICT technology/functional areas used to improve ICT-enabled TVET education. It is very important to identify the currently used ICT technologies and applications in ICT-enabled TVET research because by identifying the current research level we can link technologies

with the industry requirements through the industrial revolutions to find gaps. These gaps will provide guidelines for future research.

RQ3. What empirical and research types have been used to improve ICT-enabled TVET education and how studies have been empirically validated?

This question has two dimensions; Empirical type and Research type used to improve ICT-enabled TVET education. Empirical research is classified into three areas, (i) case study, (ii) survey, and (iii) experiment [17], [18]. Research type can be also classified into three categories; (i) evaluation research, (ii) solution proposed, and (iii) experience paper [19]. In empirical type, if any document does not fall in any of three categories or has not a clear empirical type is marked as ''No''. Similarly, in research type, if any document does not use any of three categories are marked as ''Other''. Other category means either it is an opinion paper, theoretical paper, a report, a book, general analysis of TVET, development of an algorithm, and model.

RQ4. Which industrial sectors have been focused on ICT-enabled TVET education?

This question will help to understand that specifically which industrial sectors have been focused on in literature for ICT-enabled TVET education. International Labor Organization (ILO) [20] has categorized 22 industrial sectors, these sectors have been used to label the selected literature. Literature not addressing any industrial sector has been marked as ''None'' in this category.

RQ5. Which TVET training cycle system components/functional areas have been focused on ICT-enabled TVET education?

To explore this question, initially, we have developed a TVET training cycle and categorized it into seven TVET system components/functional areas. The knowledge and expertise of the primary author have helped to develop this TVET training cycle. These seven TVET system components/functional areas are shown in Figure 1 and explained accordingly. Each selected paper has been categorized in any of the TVET training cycle components/functional areas. TVET general literature has been categorized as ''TVET Pedagogy''. The motivation of this RQ is to explore that which areas of the TVET training cycle have been focused on ICT-enabled TVET education.

RQ6. Which ICT-based applications in the teaching-learning environment have been used to improve TVET education?

This question will help to identify the teaching-learning environments which have been used in ICT-enabled TVET education. United Nations Education, Scientific, and Cultural Organization (UNESCO) have identified and recommended nine teaching-learning environments in ICT's for TVET [12]. These nine teaching-learning environments are used to get the answer to this question which includes (i) Distance Education, (ii) Blended Learning, (iii) Flexible Learning, (iv) Mobile Learning, (v) Open Education courseware and Open Courseware, (vi) Massive open online courses (MOOCs), (vii) Augmented Reality/Virtual Reality, (viii) Simulation, Games and Role Plays and (ix) 3D Printing. Literature not addressing any teaching-learning environment is marked as ''None''.

B. SEARCH STRATEGY

This section explains how this SLR search is planned and executed. Firstly, we build a search term/string to extract relevant literature from selected databases/libraries. Then, literature source selection followed procedure, its documentation, and quality assurance using the database is explained under the subsection of 3.2.1 and 3.2.2 respectively.

1) SEARCH TERMS

To build a search string, we identified keywords with the maximum possible alternatives. For example, in Asia, the TVET abbreviation is commonly used to refer to Technical and Vocational Education and Training but in certain parts of Europe, the VET abbreviation has been used as an alternative for Vocational Education Training. Similarly, in some countries of America, the Higher Vocational Education term is used to refer to and split the TVET education level. Therefore, along with the TVET keyword, we have used ''Technical Education'' and ''Vocational Education'' explicitly with the combination of ''ICT'' to identify maximum literature. Table 1 shows the databases and their executed search strings. ICT is a commonly used term in Information Technologies.

2) LITERATURE SOURCE AND SEARCH PROCEDURE

To explore the broadest spectrum of databases, we have selected eleven literature sources: ACM Digital Library (DL), IEEExplore DL, Science Direct, Springer Link, Wiley Online Library, PLOS, J Store, ArXiv, Sage, Taylor & Francis, and ERIC. The reason for selecting these literature databases aims towards three objectives: (1), covering most of the computer science with TVET literature, (2) covering most journals having impact factors, (3) selecting as exhaustive as possible for journals, book chapters, reports, conferences, and journals. Figure 2 shows the steps followed for the literature selection of this SLR.

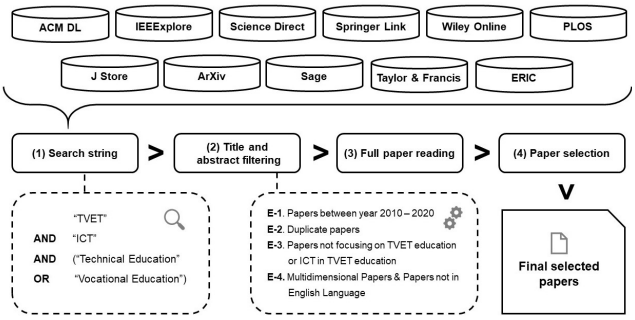

FIGURE 2. Illustration of the search procedure followed for the SLR.

To extract relevant studies and to ensure quality assurance, we have observed the following procedure:-

TABLE 1. Search string executed on libraries.

Databases	Search String
ACM DL	"TVET" AND "ICT" AND ("Technical Education" OR "Vocational Education")
IEEExplore	((("All Metadata":TVET) AND "All Metadata":ICT) AND "All Metadata":Technical Education OR Vocational Education)
Science Direct	"TVET" AND "ICT" AND ("Technical Education" OR "Vocational Education")
Springer Link	'"TVET" AND "ICT" AND ("Technical Education" OR "Vocational Education")'
Wiley Online Library	'"TVET" AND "ICT" AND ("Technical Education" OR "Vocational Education")"
PLOS	((everything:TVET) AND everything:ICT) AND everything:"Technical Education") OR everything:"Vocational Education"
J Store	"TVET" AND "ICT" AND ("Technical Education" OR "Vocational Education")
ArXiv	order: -announced_date_first; size: 50; date_range: from 2010-01-01 to 2020-12-31; include_cross_list: True; terms: AND title=TVET; AND title=ICT; AND title=Technical Education; OR title=Vocational Education
Sage	[All "tvet"] AND [All "ict"] AND [[All "technical education"] OR [All "vocational education"]]
Taylor & Francis	[All: "tvet"] AND [All: "ict"] AND [[All: "technical education"] OR [All: "vocational education"]] AND [Publication Date: (01/01/2010 TO 12/31/2020)]
ERIC	"TVET" AND "ICT" AND ("Technical Education" OR "Vocational Education")

1. A quality assurance database is developed in Excel to ensure inclusion and exclusion criteria defined in section 3.3 as well as to segregate selected papers information as defined in research questions in section 3.1.
2. The search string is executed in the search engine of each eleven literature databases.
3. An initial filtering stage is carried out by checking titles and abstracts.
4. Then, a more exhaustive filtering criterion is applied using inclusion/exclusion criteria and non-relevant literature is removed.
5. Final selected papers are downloaded and stored in reference management tool "Zotero" for identification and segregation.
6. Full paper reading is done for the selected papers for further detailed extraction.
7. Quality evaluation scores and studies addressing the RQs matrix are developed in Excel.
8. Result summaries and graphs are developed in Excel

C. STUDY SELECTION

To ensure quality assurance and to follow the four filtering stages defined in Figure 2, we have established a well-defined inclusion/exclusion criterion. These criteria are given below:-

1) INCLUSION CRITERIA

I-1. Publications containing topics related to ICT-enabled TVET education.

I-2. Publications containing ICT enabled "Technical Education" or "Vocational Education"

2) EXCLUSION CRITERIA

E-1. Papers from between the year 2010 to the year 2020

E-2. Remove duplicate papers

E-3. Papers not focusing on TVET education or ICT in TVET education

E-4. Multidimensional Papers & Papers not in the English Language

D. DATA EXTRACTION

The complete search process has been well documented using reference manager software "Zotero" and the Microsoft Excel database. During the entire data extraction process, we have carefully annotated the inclusion and exclusion criteria for each selected paper. Selected papers full texts were retrieved and for each selected paper, the following information is extracted: -

1. Where (publication channel, source, Country) and when the paper is published?
2. Which ICT technology area (if any) it has used to facilitate ICT-enabled TVET education?
3. What is the empirical and research type of paper?
4. Which specific industry it is focusing on (if any)?
5. Which TVET system component/functional area is being addressed?
6. Which teaching-learning environment (if any) it has used to enable ICT-aided TVET education?

With the above-extracted information, we should be able to provide answers to each research question posed in this systematic literature review.

E. SYSTEMATIC REVIEW EXECUTION

This section explains the SLR search execution and research data selection process. Figure 3 shows the details of steps carried out, filter criteria, and result selection. The search string mentioned in Table 1 along with E1 filter criteria of date range between January 2010 to December 2020 were executed carefully in all selected literature databases. Initially, a total of 2,445 relevant documents were found. Then E2 criteria for duplicate papers removal reduces 196 papers thus identified documents were reduced to 2,249. Similarly, after applying the E3 criteria, 2,061 papers were removed, and the 188 papers were left. E4 criteria of multidimensional focus

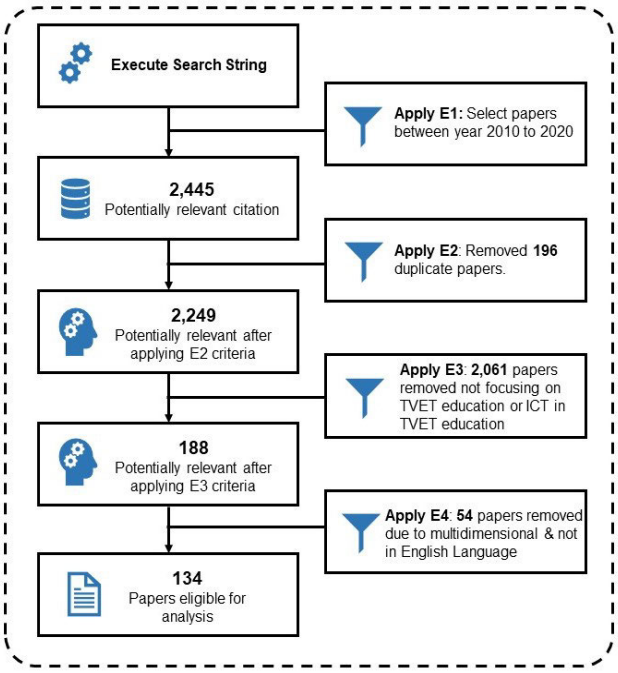

FIGURE 3. Summary of systematic review execution.

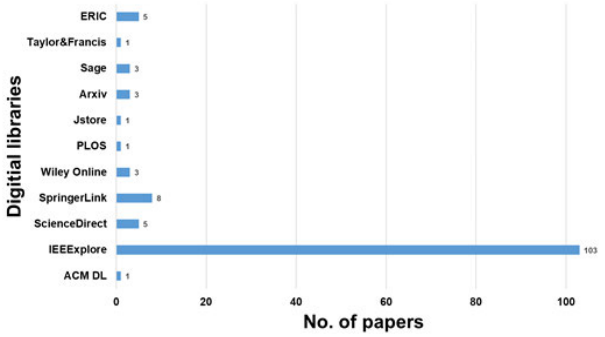

FIGURE 4. Major publication libraries.

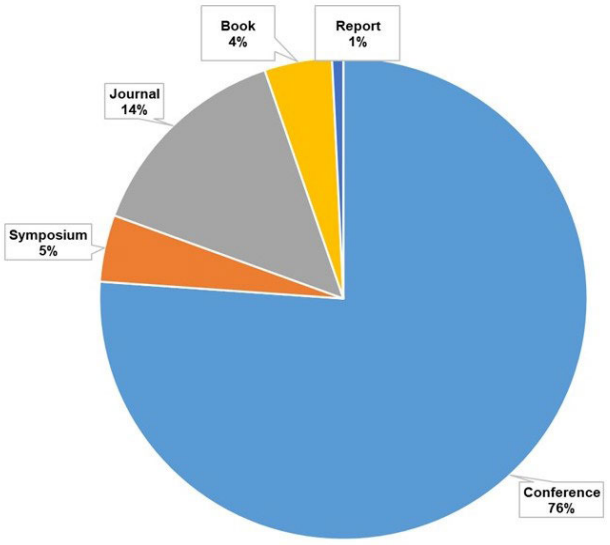

FIGURE 5. Publication types percentage's.

and non-English language further reduced 54 documents. Finally, 134 papers were selected for this study.

The classification details of these 134 final selected documents are mentioned in Table 10. Table 10 contains the column of citation reference as ''Reference'', publication channel as ''P. Channel'', publication year as ''P. Year'', empirical research type as ''Empirical Type'', research type as ''Research Type'', TVET training cycle area as ''TVET Area'', industry-focused as ''Industry Focused'', teaching/learning dimension as ''Teaching/Learning Area'' and technology used to in ICT enabled TVET as ''Technology Focused''.

IV. RESULTS

This section presents the results of SLR research questions raised in section 3.1. The result of each research question has been extracted and elaborated separately.

A. RQ1. WHICH ARE MAJOR RESEARCH PUBLICATION CHANNELS FOR ICT-ENABLED TVET EDUCATION?

To get the answer to this question, four dimensions of ICT-enabled TVET are focused. These dimensions include (i) major publication libraries, (ii) published type, (iii) year-wise publication, and (iv) publication countries. After reviewing the literature, major publication libraries for ICT-enabled TVET education research have been identified and results are shown in Figure 4 cluster bar chart. The chart includes the name of libraries and their published number of documents.

A maximum of 103 documents for ICT-enabled TVET has been published in IEEExplore digital library during the last decade. IEEExplore has contributed 76.87% of the selected study. SpringerLink digital library has published 8 documents in the last decade which is 5.96% of the selected study. The remaining libraries have publications of articles between 1 to 5 numbers in the last ten years. The over picture publication libraries show that except IEEExplore, no other digital library has focused on ICT-enabled TVET education particularly and ignored this important educational stream.

As far as research publication types are concerned, Figure 5 pie chart shows the details of publication types of the last 10 years. The majority of 102 documents are published through conferences which are 76% of the selected study. Journals have 14% publication share, Books have 4% share, symposiums have 5% publications share and Reports have only 1 %. This analysis concludes the majority of literature published for ICT-enabled TVET is the conferences. Journals have given very limited space to TVET education. More books also need to be published.

Figure 6 clustered column shows the year-wise publications for ICT-enabled TVET education. The snapshot of the graph shows that ICT-enabled TVET education remained under consideration but with very small numbers in the

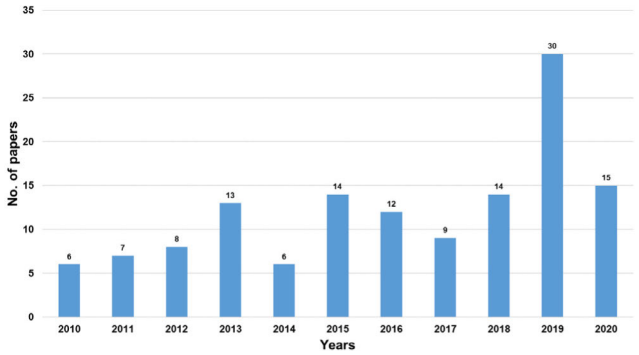

FIGURE 6. Year-wise publications.

last decade. In the year 2019, ICT-enabled TVET education has gained much importance as compared to other years and a maximum 30 number of documents were published this year. In the year 2020, only 15 documents were published. A reduction in the number of publications in the year 2020 might be due to COVID-19 pandemic irregularities. As we know that during the COVID-19 pandemic majority of educational institutes were closed. The remaining years have documents publications from 6 to 14 numbers annually.

As far as country-wise research contribution of the selected study is concerned, a total of 32 countries have contributed to the selected study. In Figure 7 Pareto chart distribution in descending order shows the countrywide number of publications.

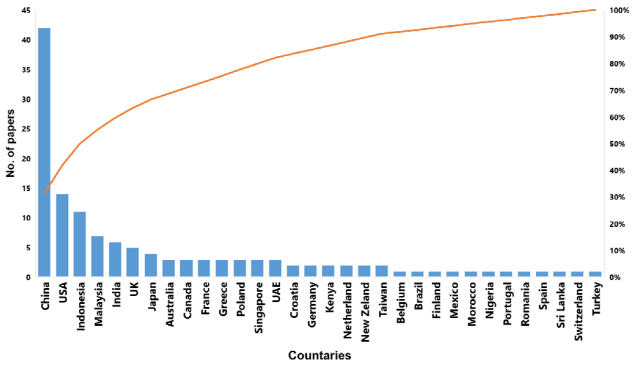

FIGURE 7. Country-wise number of publications.

China is the leading country with a maximum of 37 number publications which is 31.34% of selected papers in the last ten years. The USA is the second-largest country with 11 publications which is 10.45% of the selected study. The remaining countries have publication contributions between 1 to 11 numbers. This graph also shows that Asian countries like China, Indonesia, Malaysia, and India are focusing on ICT-enabled TVET education to support their economies. Japan, Germany, Australia, Canada, and other European countries have strong TVET/VET training systems and technologies but their research contribution in ICT-enabled TVET education is very low. There is a need for the advanced countries to share their knowledge through the publication of literature for other countries to be followed.

B. RQ2. WHICH ICT TECHNOLOGY/FUNCTIONAL AREAS HAVE BEEN FOCUSED TO IMPROVE TVET TRAINING?

In the RQ2 context, Figure 8 illustrates technology/functional areas used to deliver ICT-enabled TVET education. It is found that 57 papers i.e. 42.54% of the total selected documents have not focused on any particular ICT technology. Therefore, 77 papers which are 57.46% of the selected study have used 24 different ICT technologies/functional areas for ICT-enabled TVET education. The consistent technology area used in 17 publications is "Online Learning" in the last decade. The second most used technology in the ICT functional area in 6 publications is "Internet+Education" Remaining technology/functional areas have 1 to 5 publications in the last ten years. Technology using literature is shown in Figure 8.

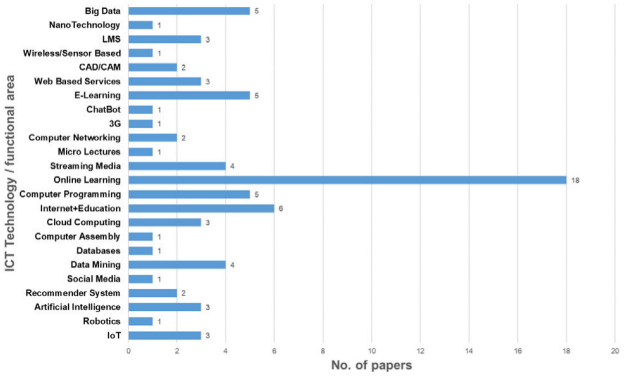

FIGURE 8. Technology/functional area focused publications.

In the same research question context, another dimension of the year-wise ICT technology-focused area in TVET is explored. The results are shown in Table 2. The snapshot of the table shows that the Industrial 4.0 revolution supported areas like Artificial Intelligence (AI), robotics, cloud computing, IoT and CAD/CAM are focused areas in the last three years but in very low numbers. Industrial 4.0 is the digital transformation of production and manufacturing. The industrial 5.0 revolution is on its way which focuses on humans working with robots and with smart machines. These industry revolutions pressingly demand (i) updated TVET curriculum and labs with the AI-supported technologies/functional areas and (ii) to train TVET teachers on these technologies to deliver effective training.

C. RQ3. WHAT EMPIRICAL AND RESEARCH TYPES HAVE BEEN USED TO IMPROVE ICT-ENABLED TVET EDUCATION AND HOW STUDIES HAVE BEEN EMPIRICALLY VALIDATED?

In this research question, ICT-enabled TVET research types have been extracted to see studies have been empirically validated. Figure 9 pie chart shows empirical research types.

TABLE 2. Yearly technology-wise publications.

Technology Area	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Big Data	-	-	-	-	-	-	-	-	2	1	2
IoT	-	-	-	-	-	1	-	-	1	1	-
Robotics	-	-	-	-	-	-	1	-	-	-	-
Artificial Intelligence	-	-	-	-	1	-	-	-	-	1	1
Recommender System	-	-	-	1	-	1	-	-	-	-	-
Social Media	-	-	-	1	-	-	-	-	-	-	-
Data Mining	-	-	-	-	-	-	1	-	1	2	-
Databases	1	-	-	-	-	-	-	-	-	-	-
Computer Assembly	-	-	-	-	-	-	-	-	1	-	-
Cloud Computing	-	-	1	-	-	1	-	-	-	-	1
Internet + Education	-	-	1	-	-	-	1	-	-	2	2
Computer Programming	1	-	1	-	-	-	-	-	2	1	-
Online Learning	1	1	1	1	-	3	1	2	-	5	2
Streaming Media	-	-	2	-	-	1	-	-	-	1	-
Micro Lectures	-	-	-	-	-	-	1	-	-	-	-
Computer Networking	-	1	-	-	-	-	-	-	1	-	-
3G	-	1	-	-	-	-	-	-	-	-	-
Chat Bot	-	-	-	-	-	-	-	1	-	-	-
E-Learning	-	1	-	2	-	-	-	-	1	1	-
Web-Based Services	-	-	-	-	-	1	-	1	-	-	1
CAD/CAM	1	-	1	-	-	-	-	-	-	-	-
Wireless/Sensor Based	-	-	-	1	-	-	-	-	-	-	-
LMS	-	-	-	-	-	-	-	-	1	1	1
Nano Technology	-	1	-	-	-	-	-	-	-	-	-

As shown in Figure 9, the highest research type in 52 documents and 39% is the solution proposed. The second-highest research type is evaluation research which is 38% and experience paper is the third which is 17% respectively. In 6% other research type includes guidelines, review, and surveys. Figure 10 shows a pie chart of studies' empirical validation.

In empirical research validation, 61 documents which are 46% of the selected study are case studies. Similarly, 38% of research is validated through experiments and 11% of research is validated through surveys. 13% of research have used various other research validation methods.

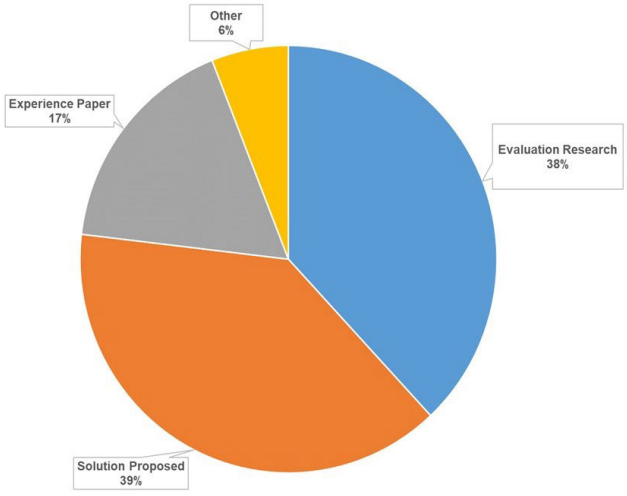

FIGURE 9. Empirical research type.

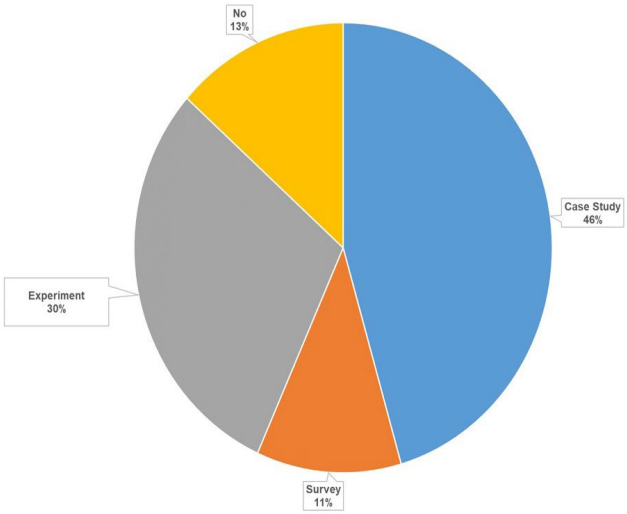

FIGURE 10. Research type percentage publication.

D. RQ4. WHICH INDUSTRIAL SECTORS HAVE BEEN FOCUSED ON ICT-ENABLED TVET EDUCATION?

Industry-specific workforce skills are very important to match industry tools, equipment, machinery, and process requirements. Industry categories defined by ILO have been for this RQ industries classification [20]. As we know the majority of industries are using modern machines, robotics, and technologies to improve their process and reduce production costs to be competitive. But this challenge is not being focused on skilled workforce training. There are internship programs that are being carried out by the industry but these are on a very small scale and cater to a very less population. We need to expand technology induction programs into the TVET training curriculum, labs, and training institutes so that industry products and services are well supported to consumers and customers.

TABLE 3. Industry wise publications.

S #	Sectors Names	No. of Publications	% age
01	Agriculture; plantations; other rural sectors	1	0.75
02	Basic Metal Production	0	-
03	Chemical industries	0	-
04	Commerce	2	1.49
05	Construction	0	-
06	Education	0	-
07	Financial services; professional services	0	-
08	Food; drink; tobacco	0	-
09	Forestry; wood; pulp and paper	0	-
10	Health services	1	0.75
11	Hotels; tourism; catering	0	-
12	Mining (coal; other mining)	0	-
13	Mechanical and electrical engineering	4	2.99
14	Media; culture; graphical	0	-
15	Oil and gas production; oil refining	0	-
16	Postal and telecommunications services	0	-
17	Public service	0	-
18	Shipping; ports; fisheries; inland waterways	1	0.75
19	Textiles; clothing; leather; footwear	0	-
20	Transport (including civil aviation; railways; road transport)	1	0.75
21	Transport equipment manufacturing	0	-
22	Utilities (water; gas; electricity)	0	-
23	None	124	92.54
	TOTAL >>	**134**	

Table 3 shows the industry used to improve ICT-enabled TVET education for the selected study. In this RQ study, we found that 92.54% of the 124 papers did not focus on any specific industry in ICT-enabled TVET education. Only 10 documents which are 7.46% of a total of 134 selected literature have focused on any industry. The highest 2.99% focused industry is mechanical and electrical engineering. Table 3 shows the detail of all industries ' data.

The data of RQ4 also reveals another aspect of ICT-enabled TVET Education. In the real world, we can experience new products, services, and technologies in our daily life. If these products, services, and technical support knowledge is not inculcating in the curriculum and labs then there may be a problem of skilled workforce shortage in the future. Therefore, policymakers, TVET training institutes, industry, academia, and researchers need to focus on this aspect so that a skilled workforce can be produced.

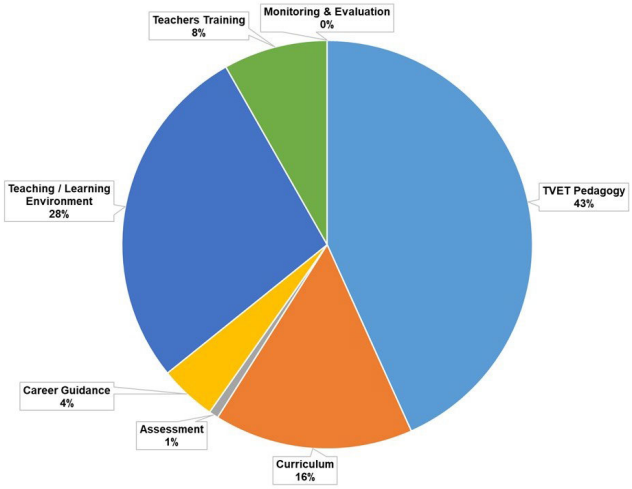

FIGURE 11. TVET Training cycle system components/functional areas research.

E. RQ5. WHICH TVET TRAINING CYCLE SYSTEM COMPONENTS/FUNCTIONAL AREAS HAVE BEEN FOCUSED ON ICT-ENABLED TVET EDUCATION?

We have presented the TVET training cycle in Figure 1. This training cycle is used to explore the answer to RQ5. The purpose of the TVET training cycle is to show the logical sequence of the entire TVET training program. The answer of RQ5 will help us to understand which areas of the TVET training cycle have a focus for publications and which areas need more attention to improve ICT-enabled TVET education. Figure 11 pie chart shows the TVET training cycle system components and functional areas focused document result for 134 selected documents. TVET pedagogy is the majority focus area in 58 document publications which is 43% of the selected study. The second focused area is a teaching/learning environment which is 28% through 37 publish documents. The third focus is the curriculum which is 16%. The outcome of the TVET training system is how trainees performed during the training? Has he/she got a job? and how the overall training system has performed? All these questions can get answered through trainee assessment, career guidance, and monitoring & evaluation of the entire TVET training system. All these areas have very low focus. The assessment has been focused on 1% of literature and career guidance has been focused on 4% of literature and monitoring and evaluation have not been used in any literature on ICT-enabled TVET education. Digitized monitoring and evaluation of training programs are being effectively used in school education and higher education. This gap needs to be addressed to build an effective TVET training system and programs. Monitoring and evaluation system component work based on key performance indicators.

F. RQ6. WHICH ICT-BASED APPLICATIONS IN THE TEACHING LEARNING ENVIRONMENT HAVE BEEN USED TO IMPROVE TVET EDUCATION?

To get the answer to this research question, we have used UNESCO identified nine (09) teaching-learning environments in ICT's for TVET [12]. Figure 12 cluster bar chart shows the teaching-learning environment and their number of publications.

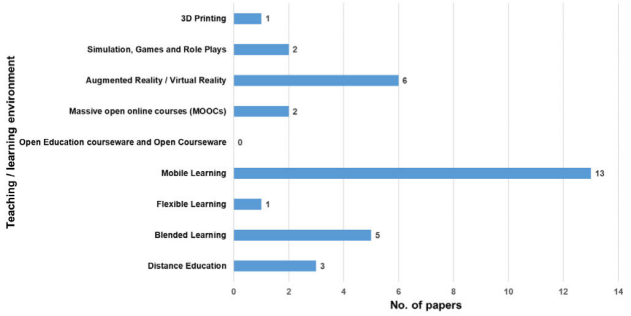

FIGURE 12. Teaching/Learning environment publications.

101 publications i.e. 75.37% of the total selected study have not used any teaching/learning environment in ICT-enabled TVET education. Publications not using any technology have been excluded from Figure 12. In the remaining 33 selected documents, Mobile learning has a maximum share which is 9.70% of the total study selection. All remaining areas are shown in Figure 12. These teaching/learning environments are successfully being used in school education and higher education. In TVET education, this transformation is in process and needs more attention to widespread TVET education.

V. QUALITY EVALUATIONS

To evaluate the quality of the selected literature, two dimensions have been analyzed. The first dimension is the matrix of literature and their evaluation that whether this study is answering the raised research question with the criteria of "Yes" and "No". Table 4 shows the matrix of selected literature and research question answered or not details.

In the second dimension, we have ranked the selected literature. We have applied the score ranking criteria which has been already used in [150], [151]. All 134 documents have been evaluated for each RQ individually and ranked according to the below-scoring strategy: -

Maximum Score for all RQs = 7

1. RQ1: For Journal literature Score is "2" for Book source score is "1.5" for Conference & Symposium score is "1" and for report score "0.5"
2. RQ2: If ICT technology is used in literature then "1" else "0"
3. RQ3: If empirical and research type is followed then "1" else "0"
4. RQ4: If the study particularly referred to any industrial sector specifically then "1" else "0"

TABLE 4. Studies addressing the research questions.

Ref.	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6
[21]	Yes	No	Yes	No	Yes	No
[22]	Yes	Yes	Yes	Yes	Yes	No
[23]	Yes	No	Yes	No	Yes	Yes
[24]	Yes	Yes	Yes	No	Yes	No
[25]	Yes	No	Yes	No	Yes	Yes
[26]	Yes	No	Yes	No	Yes	No
[27]	Yes	Yes	Yes	No	Yes	No
[28]	Yes	Yes	Yes	No	Yes	Yes
[29]	Yes	Yes	Yes	No	Yes	Yes
[30]	Yes	Yes	Yes	No	Yes	No
[31]	Yes	Yes	Yes	No	Yes	No
[32]	Yes	Yes	Yes	No	Yes	No
[33]	Yes	Yes	Yes	No	Yes	Yes
[34]	Yes	Yes	Yes	No	Yes	No
[35]	Yes	Yes	Yes	No	Yes	No
[36]	Yes	Yes	Yes	No	Yes	Yes
[37]	Yes	Yes	Yes	No	Yes	Yes
[38]	Yes	No	Yes	No	Yes	Yes
[39]	Yes	Yes	Yes	No	Yes	No
[40]	Yes	Yes	Yes	No	Yes	No
[41]	Yes	No	Yes	No	Yes	No
[42]	Yes	No	Yes	No	Yes	No
[43]	Yes	Yes	Yes	No	Yes	No
[44]	Yes	Yes	Yes	No	Yes	No
[45]	Yes	Yes	Yes	No	Yes	No
[46]	Yes	Yes	Yes	Yes	Yes	Yes
[47]	Yes	Yes	Yes	Yes	Yes	No
[48]	Yes	Yes	Yes	No	Yes	No
[49]	Yes	Yes	Yes	No	Yes	No
[50]	Yes	No	Yes	Yes	Yes	No
[51]	Yes	Yes	Yes	No	Yes	No

TABLE 4. *(Continued.)* Studies addressing the research questions.

[52]	Yes	No	Yes	Yes	Yes	Yes
[53]	Yes	Yes	Yes	No	Yes	No
[54]	Yes	Yes	Yes	No	Yes	Yes
[55]	Yes	Yes	Yes	No	Yes	No
[56]	Yes	Yes	Yes	No	Yes	No
[57]	Yes	No	Yes	No	Yes	Yes
[58]	Yes	No	Yes	Yes	Yes	Yes
[59]	Yes	Yes	Yes	No	Yes	Yes
[60]	Yes	Yes	Yes	No	Yes	No
[61]	Yes	Yes	Yes	No	Yes	No
[62]	Yes	No	Yes	No	Yes	Yes
[63]	Yes	No	Yes	No	Yes	No
[64]	Yes	Yes	Yes	No	Yes	No
[65]	Yes	Yes	Yes	No	Yes	No
[66]	Yes	Yes	Yes	No	Yes	No
[67]	Yes	No	Yes	No	Yes	Yes
[68]	Yes	Yes	Yes	No	Yes	No
[69]	Yes	No	Yes	No	Yes	No
[70]	Yes	Yes	Yes	No	Yes	Yes
[71]	Yes	Yes	Yes	No	Yes	No
[72]	Yes	Yes	Yes	No	Yes	No
[73]	Yes	Yes	Yes	No	Yes	No
[74]	Yes	No	Yes	No	Yes	No
[75]	Yes	Yes	Yes	No	Yes	No
[76]	Yes	Yes	Yes	No	Yes	No
[77]	Yes	Yes	Yes	No	Yes	No
[78]	Yes	No	Yes	No	Yes	Yes
[79]	Yes	Yes	Yes	No	Yes	No
[80]	Yes	Yes	Yes	No	Yes	No
[81]	Yes	Yes	Yes	No	Yes	No
[82]	Yes	Yes	Yes	No	Yes	No
[83]	Yes	Yes	Yes	No	Yes	No
[84]	Yes	Yes	Yes	No	Yes	Yes

TABLE 4. *(Continued.)* Studies addressing the research questions.

[85]	Yes	No	Yes	No	Yes	No
[86]	Yes	Yes	Yes	No	Yes	No
[87]	Yes	Yes	Yes	No	Yes	No
[88]	Yes	Yes	Yes	No	Yes	No
[89]	Yes	Yes	Yes	No	Yes	No
[90]	Yes	No	Yes	No	Yes	Yes
[91]	Yes	No	Yes	Yes	Yes	No
[92]	Yes	Yes	Yes	No	Yes	Yes
[10]	Yes	No	Yes	No	Yes	Yes
[93]	Yes	No	Yes	No	Yes	No
[94]	Yes	Yes	Yes	No	Yes	Yes
[95]	Yes	Yes	Yes	No	Yes	No
[96]	Yes	Yes	Yes	No	Yes	No
[97]	Yes	No	Yes	No	Yes	No
[98]	Yes	Yes	Yes	No	Yes	No
[99]	Yes	Yes	Yes	No	Yes	No
[100]	Yes	Yes	Yes	No	Yes	No
[101]	Yes	No	Yes	No	Yes	No
[102]	Yes	No	Yes	Yes	Yes	No
[103]	Yes	Yes	Yes	No	Yes	No
[104]	Yes	Yes	Yes	No	Yes	No
[105]	Yes	Yes	Yes	No	Yes	No
[106]	Yes	No	Yes	No	Yes	No
[107]	Yes	No	Yes	No	Yes	No
[108]	Yes	Yes	Yes	No	Yes	No
[109]	Yes	No	Yes	No	Yes	No
[11]	Yes	No	Yes	No	Yes	No
[110]	Yes	No	Yes	No	Yes	No
[111]	Yes	No	Yes	No	Yes	Yes
[112]	Yes	No	Yes	No	Yes	No
[113]	Yes	Yes	Yes	No	Yes	Yes
[114]	Yes	No	Yes	No	Yes	No
[115]	Yes	No	Yes	No	Yes	No

TABLE 4. *(Continued.)* **Studies addressing the research questions.**

[116]	Yes	No	Yes	No	Yes	No
[117]	Yes	No	Yes	No	Yes	No
[118]	Yes	No	Yes	No	Yes	No
[119]	Yes	No	Yes	No	Yes	No
[120]	Yes	No	Yes	No	Yes	Yes
[121]	Yes	No	Yes	No	Yes	Yes
[122]	Yes	No	Yes	No	Yes	No
[123]	Yes	No	Yes	No	Yes	No
[124]	Yes	No	Yes	No	Yes	No
[125]	Yes	No	Yes	No	Yes	Yes
[126]	Yes	No	Yes	No	Yes	No
[127]	Yes	Yes	Yes	No	Yes	Yes
[58]	Yes	Yes	Yes	Yes	Yes	No
[128]	Yes	Yes	Yes	No	Yes	No
[129]	Yes	No	Yes	No	Yes	No
[130]	Yes	No	Yes	No	Yes	No
[131]	Yes	No	Yes	No	Yes	No
[12]	Yes	No	Yes	No	Yes	Yes
[132]	Yes	No	Yes	No	Yes	No
[13]	Yes	No	Yes	No	Yes	No
[133]	Yes	No	Yes	No	Yes	No
[134]	Yes	No	Yes	No	Yes	No
[135]	Yes	Yes	Yes	No	Yes	No
[136]	Yes	Yes	Yes	No	Yes	No
[137]	Yes	Yes	Yes	No	Yes	No
[138]	Yes	Yes	Yes	No	Yes	Yes
[139]	Yes	Yes	Yes	No	Yes	No
[140]	Yes	Yes	Yes	No	Yes	No
[141]	Yes	No	Yes	No	Yes	No
[142]	Yes	Yes	Yes	No	Yes	No
[143]	Yes	No	Yes	No	Yes	Yes
[144]	Yes	Yes	Yes	No	Yes	Yes
[145]	Yes	Yes	Yes	No	Yes	No

TABLE 4. *(Continued.)* **Studies addressing the research questions.**

[146]	Yes	No	Yes	Yes	Yes	No
[147]	Yes	Yes	Yes	No	Yes	No
[148]	Yes	No	Yes	No	Yes	No
[149]	Yes	Yes	Yes	No	Yes	No

5. RQ5: If any TVET Training Cycle System Components/functional area used then "1" else "0"
6. RQ6: If any teaching-learning environment is used in the study then "1" else "0"

The reason for giving a maximum score to Journal in RQ1 is because normally journals have tough quality assurance criteria as compare to conferences and symposiums. Table 5 shows the details of each literature RQ score individually. The total score is also shown in the last "Total Score" column.

To summarize the ranking, Table 6 shows the quality ranking summary concerning the number of studies and its percentage from overall selected literature. 81 documents which are 60% of the selected study have gotten the quality assessment score of 4. Only 3 documents which are 2% of the selected study have a score of 6. None of the documents has scored the maximum assessment marks of 7.

To yearly summarize the ranking, Table 7 shows the year-wise quality assessment score. As shown, in the year 2019 maximum of 118 ranked quality score is observed for 30 published documents. In the year 2020, the quality score is the second largest of the decade i.e. 62. As far percentage of the ranked score is concerned, in the year 2014, a maximum percentage of 62% of the achieved score is observed. We have used the "Replication Principle" to handle uncertainty and used t-distribution to find confidence internal. Detailed statistics are shown in Table 7.

VI. LIMITATIONS

This study has the followings limitations: -

1. This study search was conducted till December 2020 therefore research published till the date in selected libraries/databases is included.
2. This systematic review is limited to the search term used and databases included.
3. ICT-enabled TVET education is empirical research that provides a snapshot of ICT penetration in different areas of TVET training programs through raised research questions mentioned in section 3.1.
4. The research question raised in RQ5 and RQ6 evaluation has been based on TVET international organization of UNESCO and ILO.
5. The first author has been working with one of the largest TVET Training providers in Punjab, Pakistan for the last 14 years. His exposure, knowledge, and contribution of large national TVET ICT enabled systems and

TABLE 5. Quality assessment evaluation.

Ref.	RQ 1	RQ 2	RQ 3	RQ 4	RQ 5	RQ 6	Total Score
[21]	1	0	1	0	1	0	3
[22]	1	1	1	1	1	0	5
[23]	1	0	1	0	1	1	4
[24]	1	1	1	0	1	0	4
[25]	1	0	1	0	1	1	4
[26]	1	0	1	0	1	0	3
[27]	1	1	1	0	1	0	4
[28]	1	1	1	0	1	1	5
[29]	1	1	1	0	1	1	5
[30]	1	1	1	0	1	0	4
[31]	1	1	1	0	1	0	4
[32]	1	1	1	0	1	0	4
[33]	1	1	1	0	1	1	5
[34]	1	1	1	0	1	0	4
[35]	1	1	1	0	1	0	4
[36]	1	1	1	0	1	1	5
[37]	1	1	1	0	1	1	5
[38]	1	0	1	0	1	1	4
[39]	1	1	1	0	1	0	4
[40]	1	1	1	0	1	0	4
[41]	1	0	1	0	1	0	3
[42]	1	0	1	0	1	0	3
[43]	1	1	1	0	1	0	4
[44]	1	1	1	0	1	0	4
[45]	1	1	1	0	1	0	4
[46]	1	1	1	1	1	1	6
[47]	1	1	1	1	1	0	5
[48]	1	1	1	0	1	0	4
[49]	1	1	1	0	1	0	4
[50]	1	0	1	1	1	0	4
[51]	1	1	1	0	1	0	4
[52]	1	0	1	1	1	1	5
[53]	1	1	1	0	1	0	4
[54]	1	1	1	0	1	1	5
[55]	1	1	1	0	1	0	4
[56]	1	1	1	0	1	0	4
[57]	1	0	1	0	1	1	4
[58]	1	0	1	1	1	1	5
[59]	1	1	1	0	1	1	5
[60]	1	1	1	0	1	0	4
[61]	1	1	1	0	1	0	4
[62]	1	0	1	0	1	1	4
[63]	1	0	1	0	1	0	3
[64]	1	1	1	0	1	0	4
[65]	1	1	1	0	1	0	4
[66]	1	1	1	0	1	0	4
[67]	1	0	1	0	1	1	4
[68]	1	1	1	0	1	0	4
[69]	1	0	1	0	1	0	3
[70]	1	1	1	0	1	1	5
[71]	2	1	1	0	1	0	5
[72]	1	1	1	0	1	0	4
[73]	1	1	1	0	1	0	4
[74]	1	0	1	0	1	0	3
[75]	1	1	1	0	1	0	4
[76]	1	1	1	0	1	0	4
[77]	1	1	1	0	1	0	4
[78]	1	0	1	0	1	1	4
[79]	1	1	1	0	1	0	4
[80]	1	1	1	0	1	0	4
[81]	1	1	1	0	1	0	4
[82]	1	1	1	0	1	0	4
[83]	1	1	1	0	1	0	4

TABLE 5. *(Continued.)* Quality assessment evaluation.

[84]	1	1	1	0	1	1	5
[85]	1	0	1	0	1	0	3
[86]	1	1	1	0	1	0	4
[87]	1	1	1	0	1	0	4
[88]	1	1	1	0	1	0	4
[89]	1	1	1	0	1	0	4
[90]	1	0	1	0	1	1	4
[91]	1	0	1	1	1	0	4
[92]	1	1	1	0	1	1	5
[10]	1	0	1	0	1	1	4
[93]	1	0	1	0	1	0	3
[94]	1	1	1	0	1	1	5
[95]	1	1	1	0	1	0	4
[96]	1	1	1	0	1	0	4
[97]	1	0	1	0	1	0	3
[98]	1	1	1	0	1	0	4
[99]	1	1	1	0	1	0	4
[100]	1	1	1	0	1	0	4
[101]	1	0	1	0	1	0	3
[102]	1	0	1	1	1	0	4
[103]	1	1	1	0	1	0	4
[104]	1	1	1	0	1	0	4
[105]	1	1	1	0	1	0	4
[106]	1	0	1	0	1	0	3
[107]	1	0	1	0	1	0	3
[108]	1	1	1	0	1	0	4
[109]	1	0	1	0	1	0	3
[11]	1	0	1	0	1	0	3
[110]	1	0	1	0	1	0	3
[111]	1	0	1	0	1	1	4
[112]	1	0	1	0	1	0	3
[113]	1	1	1	0	1	1	5
[114]	1.5	0	1	0	1	0	3.5

TABLE 5. *(Continued.)* Quality assessment evaluation.

[115]	1.5	0	1	0	1	0	3.5
[116]	1	0	1	0	1	0	3
[117]	1.5	0	1	0	1	0	3.5
[118]	2	0	1	0	1	0	4
[119]	2	0	1	0	1	0	4
[120]	1.5	0	1	0	1	1	4.5
[121]	1.5	0	1	0	1	1	4.5
[122]	2	0	1	0	1	0	4
[123]	2	0	1	0	1	0	4
[124]	2	0	1	0	1	0	4
[125]	2	0	1	0	1	1	5
[126]	2	0	1	0	1	0	4
[127]	2	1	1	0	1	1	6
[58]	2	1	1	1	1	0	6
[128]	2	1	1	0	1	0	5
[129]	2	0	1	0	1	0	4
[130]	2	0	1	0	1	0	4
[131]	2	0	1	0	1	0	4
[12]	1.5	0	1	0	1	1	4.5
[132]	2	0	1	0	1	0	4
[13]	0.5	0	1	0	1	0	2.5
[133]	1	0	1	0	1	0	3
[134]	2	0	1	0	1	0	4
[135]	2	1	1	0	1	0	5
[136]	1	1	1	0	1	0	4
[137]	1	1	1	0	1	0	4
[138]	1	1	1	0	1	1	5
[139]	1	1	1	0	1	0	4
[140]	1	1	1	0	1	0	4
[141]	2	0	1	0	1	0	4
[142]	2	1	1	0	1	0	5
[143]	1	0	1	0	1	1	4
[144]	1	1	1	0	1	1	5

TABLE 5. *(Continued.)* **Quality assessment evaluation.**

[145]	1	1	1	0	1	0	4
[146]	1	0	1	1	1	0	4
[147]	1	1	1	0	1	0	4
[148]	1	0	1	0	1	0	3
[149]	1	1	1	0	1	0	4

TABLE 6. **Quality assessment summary.**

Score	2.5	3	3.5	4	4.5	5	6
No of Studies	1	20	3	81	3	23	3
Percentage	1%	15%	2%	60%	2%	17%	2%

TABLE 7. **Year wise quality score.**

Description	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
No of Studies	6	7	8	13	6	14	12	9	14	30	15
Total Quality Score	42	49	56	91	42	98	84	63	98	210	105
Ranked Quality Score	25	30	34	50	26	59	46	37	58	118	62
Ranked Percentage	60	61	61	55	62	60	55	58	59	56	59

t-distribution score of Ranked Quality Score	
Mean	49.41
Standard Error	7.91
Median	46.00
Mode	N/A
Standard Deviation	26.24
Sample Variance	688.79
Kurtosis	4.50
Skewness	1.88
Range	92.50
Minimum	25.00
Maximum	117.50
Sum	543.50
Count	11.00
Confidence Level (95.0%)	17.63

TVET development projects of Punjab Government with international TVET organizations like United Nations International Children's Emergency Fund (UNICEF), Japan International Cooperation Agency (JICA), The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (GIZ) and United States Agency for International Development (USAID) helped to validate this study.

6. This study is primarily carried out from the TVET training provider's point of view but its focus is providing policy guidelines to all TVET stakeholders like TVET training providers, TVET policymakers, industry, Government authorities, donor/funding agencies, researchers, and academia.

VII. CONCLUSION AND FUTURE WORK

A. CONCLUSION

In this paper, we have designed and executed a systematic literature review to find the relevant research work for ICT-enabled TVET education into 07 TVET training cycle system components/functional areas and other RQs mentioned in section 3.1. We searched 2,445 documents from 11 renowned databases/libraries from January 2010 to December 2020. After applying rigorous inclusion/exclusion criteria we finally selected 134 documents for this study. Quality assessment and ranking of selected literature have also been carried out to ensure quality assurance of the study. Below points are the conclusion of the study: -

1. Overall ICT enablement in TVET education is very low. Industry, academia, researchers, TVET policy makers, TVET training providers, and donors/funding agencies need to focus on this aspect. We can see technology advancements in our daily life products, services, and in the industry. If produced labor curriculum, labs, teachers, and teaching-learning environment is not digitally enabled with upgraded knowledge then there may be a mismatch between the produced labor and required labor.
2. IEEE Explore has contributed 76.87% in the selected study of ICT-enabled TVET education and the majority 76% of documents are published in conference proceedings. Other Journals also need to give more space to TVET education.
3. In the year 2019, a maximum number of selected studies i.e. 30 documents are published but in the year 2020, the publications number is decreased to 15 documents, which is the second-highest in the year-wise study. It seems that the COVID-19 pandemic has affected the TVET education stream like it has affected school education and higher education.
4. China has a maximum number of 37 publications contributing 31.34% of the selected study. This shows that China is investing in ICT-enabled TVET education and it might be one of the reasons that Chain is moving fast in the superpower country's race [152]. The USA has the second-highest 14 publications of 10.45% of the selected study. Similarly, other Asian countries like Malaysia, Indonesia, and India have significant contributions between 6 to 11 publications. Overall Asian countries' publications show that they are leading and investing in ICT-enabled TVET education to support their economies.
5. 57 documents which are 42.54% of the selected study have not focused on any ICT technology and functional area. 57.46% 77 documents have used 24 different ICT technology/functional areas. 18 publications have used ''online learning'' learning consistently in the last ten years.

6. In empirical/research type focus study, 39% of the documents have proposed solutions and 38% of literature have performed evaluation research.
7. 92.54% of the selected study has not focused on any industry while publishing ICT enable TVET education literature. The highest 2.99% focused industry of the selected study is Mechanical and Electrical Engineering.
8. The majority of 43% publications focus on general TVET pedagogy whereas the second highest 28% focused areas are the teaching/learning environment.
9. Finally, 101 documents which are 75.37% have not focused on any particular teaching-learning environment. 13 documents of 9.70% of publications have used mobile learning for teaching/learning environment platform. Many other teaching/learning environments like virtual education, MOOCS, online and distance education, blended learning, AR/VR, and simulations, etc., are successfully being used in school education and higher education. The literature of the study proves less focus on these teaching/learning environments in TVET education.

B. RESEARCH CONTRIBUTION

To the best of the authors' knowledge, this is the first SLR of its kind which has evaluated technology/application penetration in all components of the TVET training cycle and tried to produce new knowledge. The study revealed that general TVET pedagogy is a more focused area for a maximum of 31 research publications in the TVET training cycle. Table 8 listed TVET training cycle system components/functional areas, research citations, and literature-focused application/technology used to improve TVET training education.

The second contribution of this study is the TVET technology index. This index is based upon the ICT application/technology used in research during the last decade. We have analyzed the technology index into three clusters because we have seen the rapid change of technologies and application development in ICT. There are probability application/technologies used earlier are no longer available or upgraded. For example, 3G technology is upgraded to 4G & 5G and CAD/CAM technology and application have much improved versions nowadays. The year cluster segregation is 5 years, 3 years, and 2 years respectively. Cluster 1 is between January 2010 to December 2014; Cluster 2 is between January 2015 to December 2018, and Cluster 3 is between January 2019 to December 2020. Table 9 shows the TVET technology index.

The visual representation of the technology index is shown in Figure 13. Online training has gained much importance during the last two years because of the COVID-19 pandemic.

Industry 4.0 and 5.0 industry revolution technologies like Robotics, Artificial Intelligence, Big Data, Data Science, Recommender Systems, Nano Technology, Cloud

TABLE 8. Summary of Applications/Technology used in TVET training.

TVET Training Cycle Area	Research Publications	Applications / Technology Used
TVET Pedagogy (31 Publications)	(11 Nos.) [29], [33], [39], [45], [68], [70], [98], [104], [127], [135], [136]	Online Learning Internet+Education Cloud Computing
	(04 Nos.) [60], [66], [137], [144]	Big Data Data Mining
	(02 Nos.) [22], [84]	IoT
	(02 Nos.) [32], [145]	E-Learning
	(02 Nos.) [80], [83]	Robotics
	(01 No.) [40]	LMS
	(01 No.) [65]	Artificial Intelligence
	(01 No.) [71]	Recommender System
	(01 No.) [94]	CAD/CAM
	(01 No.) [95]	Nano Technology
	(01 No.) [96]	Web-Based Services
	(01 No.) [113]	Computer Programming
	(01 No.) [128]	
	(01 No.) [147]	
	(01 No.) [53]	
Curriculum (13 Publications)	(03 Nos.) [27], [35], [99]	Computer Programming Online Learning
	(02 Nos.) [30], [100]	Streaming Media
	(02 Nos.) [48], [82]	Internet+Education
	(01 No.) [28]	Micro Lectures
	(01 No.) [34]	Computer Networking
	(01 No.) [43]	CAD/CAM
	(01 No.) [76]	IoT
	(01 No.) [105]	Cloud Computing
	(01 No.) [142]	
Assessment	**None**	**None**
Career Guidance (04 Publications)	(02 No.) [75], [108]	Data Mining Web-Based Service
	(01 No.) [55]	Big Data
	(01 No.) [61]	
Teaching / Learning Environment (25 Publications)	(05 Nos.) [47], [64], [79], [86], [140]	Online Learning E-Learning LMS
	(03 Nos.) [51], [54], [103]	Artificial Intelligence
	(02 Nos.) [58], [149]	Big Data
	(02 Nos.) [118], [138]	Computer Networking
	(02 Nos.) [72], [139]	Streaming Media
	(01 No.) [36]	3G
	(01 No.) [37]	ChatBot
	(01 No.) [46]	IoT

TABLE 8. *(Continued.)* **Summary of Applications/Technology used in TVET training.**

	(01 No.) [49]	Computer Assembly
	(01 No.) [56]	Social Media
	(01 No.) [99]	Recommender System
	(01 No.) [73]	Wireless/Sensor Based
	(01 No.) [87]	Web-Based Service
	(01 No.) [88]	Computer Programming
	(01 No.) [89]	
	(01 No.) [92]	
Teachers Training	(01 No.) [24]	Internet+Education
	(01 No.) [31]	Streaming Media
(04 Publications)	(01 No.) [77]	E-Learning
	(01 No.) [81]	Databases
Monitoring & Evaluation	**None**	**None**

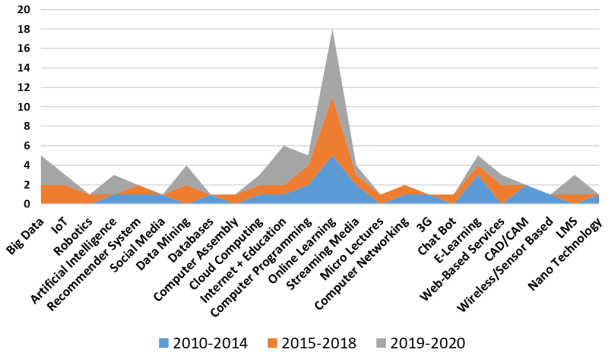

FIGURE 13. Technology penetration three clusters.

Computing, and IoT, etc. are very less focused. These technologies are the future building blocks of the TVET curriculum, labs, training delivery, and teacher training. Therefore, this gap must be filled by TVET training providers, the policymakers, industry, academia, and researchers.

In TVET training, trainee assessment and monitoring and evaluation have gained importance in recent years. These are the two key areas to gauge the output and outcome of the TVET training programs. TVET program output is the quality of TVET graduates/skilled workforce being produced and TVET outcome the overall effectiveness of the programs. The quality of TVET graduates will help to upgrade the TVET curriculum, labs, teaching-learning environment, and teacher's training. Similarly, monitoring and evaluation through Key Performance Indicators (KPIs) will help to evaluate the overall effectiveness of training programs. Career guidance and teacher's training also fewer focus areas with only 4 publications. All these areas need focus.

To improve overall TVET training cycle components/ functional areas, there is a need to integrate all stakeholders through systems and digitized processes. These systems can be TVET trainee/skilled workforce pools, labor management system, career guidance system and digital curriculum delivery system, etc. The development of a common framework to integrate all TVET stakeholders will not only help to produce an industry-required skilled workforce but will also address the skill shortage problem worldwide.

TABLE 9. TVET technology index.

Technology Focused	2010-2014	2015-2018	2019-2020
Big Data	0	2	3
IoT	0	2	1
Robotics	0	1	0
Artificial Intelligence	1	0	2
Recommender System	1	1	0
Social Media	1	0	0
Data Mining	0	2	2
Databases	1	0	0
Computer Assembly	0	1	0
Cloud Computing	1	1	1
Internet + Education	1	1	4
Computer Programming	2	2	1
Online Learning	5	6	7
Streaming Media	2	1	1
Micro Lectures	0	1	0
Computer Networking	1	1	0
3G	1	0	0
Chat Bot	0	1	0
E-Learning	3	1	1
Web-Based Services	0	2	1
CAD/CAM	2	0	0
Wireless/Sensor Based	1	0	0
LMS	0	1	2
Nano Technology	1	0	0

C. POTENTIAL AREAS FOR FUTURE RESEARCH

Analyzing the past to predict the future is meaningless without a future research agenda [153]. This SLR has identified gaps that need the attention of (i) TVET training institutes to upgrade their curriculum, labs and, equipment, (ii) policymakers to devise technology-oriented, skilled workforce development policies, (iii) to provide guidelines to industry, researchers, Governments, funding agencies/donors and academics to focus on upcoming challenges of workforce development. Below is our proposed future research agenda:-

1. Journals and books publisher need to give more space to TVET education to support ICT-enabled TVET education initiatives.

TABLE 10. Classification results.

Reference	P. Channel	P. Year	Empirical Type	Research Type	TVET Area	Industry Focused	Teaching / Learning Area	Technology Focused
[21]	Conference	2019	Survey	Evaluation Research	Teaching / Learning Environment	None	None	None
[22]	Symposium	2012	Case Study	Experience Paper	TVET Pedagogy	Health services	None	Cloud Computing
[23]	Conference	2010	Experiment	Solution Proposed	Curriculum	None	Augmented Reality / Virtual Reality	None
[24]	Conference	2016	Experiment	Solution Proposed	Teachers Training	None	None	Internet+Education
[25]	Conference	2010	Experiment	Evaluation Research	Curriculum	None	Simulation, Games and Role Plays	None
[26]	Conference	2019	Case Study	Solution Proposed	Teachers Training	None	None	None
[27]	Conference	2010	Case Study	Solution Proposed	Curriculum	None	None	Computer Programming
[28]	Conference	2019	Experiment	Solution Proposed	Curriculum	None	Blended Learning	Internet+Education
[29]	Symposium	2017	Case Study	Evaluation Research	TVET Pedagogy	None	Blended Learning	Online Learning
[30]	Conference	2017	Experiment	Solution Proposed	Curriculum	None	None	Online Learning
[31]	Conference	2015	Case Study	Solution Proposed	Teachers Training	None	None	Streaming Media
[32]	Conference	2019	No	Other	TVET Pedagogy	None	None	Big Data
[33]	Conference	2015	Case Study	Solution Proposed	TVET Pedagogy	None	3D Printing	Online Learning
[34]	Conference	2016	Case Study	Solution Proposed	Curriculum	None	None	Micro Lectures
[35]	Conference	2012	No	Solution Proposed	Curriculum	None	None	Computer Programming
[36]	Conference	2018	Case Study	Solution Proposed	Teaching / Learning Environment	None	Augmented Reality / Virtual Reality	Computer Networking
[37]	Conference	2012	Case Study	Solution Proposed	Teaching / Learning Environment	None	Mobile Learning	Streaming Media
[38]	Conference	2015	No	Evaluation Research	TVET Pedagogy	None	Mobile Learning	None
[39]	Symposium	2015	No	Other	TVET Pedagogy	None	None	Online Learning
[40]	Conference	2018	Survey	Evaluation Research	TVET Pedagogy	None	None	IoT
[41]	Conference	2019	Case Study	Evaluation Research	Teaching / Learning Environment	None	None	None
[42]	Conference	2019	No	Other	TVET Pedagogy	None	None	None
[43]	Conference	2011	Case Study	Evaluation Research	Curriculum	None	None	Computer Networking
[44]	Conference	2019	Experiment	Experience Paper	Teaching / Learning Environment	None	None	Artificial Intelligence
[45]	Conference	2019	No	Other	TVET Pedagogy	None	None	Online Learning
[46]	Conference	2011	Experiment	Solution Proposed	Teaching / Learning Environment	Mechanical and electrical engineering	Mobile Learning	3G
[47]	Conference	2010	No	Solution Proposed	Teaching / Learning Environment	Commerce	None	Online Learning
[48]	Conference	2012	Case Study	Solution Proposed	Curriculum	None	None	Streaming Media
[49]	Conference	2017	Experiment	Solution Proposed	Teaching / Learning Environment	None	None	ChatBot
[50]	Symposium	2013	No	Solution Proposed	Curriculum	Commerce	None	None
[51]	Conference	2013	Case Study	Experience Paper	Teaching / Learning Environment	None	None	E-Learning
[52]	Conference	2014	Experiment	Solution Proposed	Curriculum	Mechanical and electrical engineering	Mobile Learning	None
[53]	Conference	2018	Experiment	Experience Paper	TVET Pedagogy	None	None	Computer Programming
[54]	Conference	2013	No	Solution Proposed	Teaching / Learning Environment	None	Augmented Reality / Virtual Reality	E-Learning

TABLE 10. *(Continued.)* **Classification results.**

[55]	Conference	2017	Experiment	Solution Proposed	Career Guidance	None	None	Web Based Services
[56]	Symposium	2015	Case Study	Solution Proposed	Teaching / Learning Environment	None	None	IoT
[57]	Conference	2015	Case Study	Solution Proposed	TVET Pedagogy	None	Mobile Learning	None
[58]	Conference	2019	Experiment	Evaluation Research	TVET Pedagogy	Mechanical and electrical engineering	Mobile Learning	None
[59]	Conference	2017	Experiment	Solution Proposed	Teaching / Learning Environment	None	Simulation, Games and Role Plays	Computer Assembly
[60]	Conference	2012	Case Study	Experience Paper	TVET Pedagogy	None	None	Internet+Education
[61]	Conference	2018	Case Study	Solution Proposed	Career Guidance	None	None	Big Data
[62]	Conference	2015	Experiment	Evaluation Research	Teaching / Learning Environment	None	Blended Learning	None
[63]	Conference	2018	Survey	Solution Proposed	Teaching / Learning Environment	None	None	None
[64]	Conference	2011	Case Study	Solution Proposed	Teaching / Learning Environment	None	None	Online Learning
[65]	Conference	2011	Experiment	Evaluation Research	TVET Pedagogy	None	None	E-Learning
[66]	Conference	2019	No	Solution Proposed	TVET Pedagogy	None	None	Internet+Education
[67]	Conference	2014	Experiment	Solution Proposed	Teaching / Learning Environment	None	Mobile Learning	None
[68]	Conference	2019	Survey	Experience Paper	TVET Pedagogy	None	None	Online Learning
[69]	Conference	2016	Case Study	Experience Paper	Curriculum	None	None	None
[70]	Conference	2015	Experiment	Evaluation Research	TVET Pedagogy	None	Flexible Learning	Online Learning
[71]	Journal	2016	No	Evaluation Research	TVET Pedagogy	None	None	Robotics
[72]	Conference	2018	No	Experience Paper	Teaching / Learning Environment	None	None	Big Data
[73]	Conference	2013	Case Study	Experience Paper	Teaching / Learning Environment	None	None	Social Media
[74]	Conference	2019	Experiment	Solution Proposed	Curriculum	None	None	None
[75]	Conference	2019	Case Study	Evaluation Research	Career Guidance	None	None	Data Mining
[76]	Conference	2010	Case Study	Solution Proposed	Curriculum	None	None	CAD/CAM
[77]	Conference	2018	Experiment	Evaluation Research	Teachers Training	None	None	E-Learning
[78]	Conference	2016	Experiment	Experience Paper	Teaching / Learning Environment	None	Blended Learning	None
[79]	Conference	2016	Case Study	Evaluation Research	Teaching / Learning Environment	None	None	Online Learning
[80]	Conference	2016	Experiment	Evaluation Research	TVET Pedagogy	None	None	Data Mining
[81]	Conference	2010	Experiment	Experience Paper	Teachers Training	None	None	Databases
[82]	Conference	2019	Experiment	Solution Proposed	Curriculum	None	None	Streaming Media
[83]	Conference	2018	Case Study	Evaluation Research	TVET Pedagogy	None	None	Data Mining
[84]	Conference	2015	Experiment	Solution Proposed	TVET Pedagogy	None	Mobile Learning	Cloud Computing
[85]	Conference	2019	Case Study	Solution Proposed	Curriculum	None	None	None
[86]	Conference	2019	Experiment	Experience Paper	Teaching / Learning Environment	None	None	Online Learning
[87]	Conference	2013	Case Study	Solution Proposed	Teaching / Learning Environment	None	None	Recommender System
[88]	Conference	2013	Experiment	Solution Proposed	Teaching / Learning Environment	None	None	Wireless/Sensor Based
[89]	Conference	2015	Experiment	Solution Proposed	Teaching / Learning Environment	None	None	Web Based Services
[90]	Conference	2014	Experiment	Experience Paper	TVET Pedagogy	None	Augmented Reality / Virtual Reality	None
[91]	Conference	2011	Case Study	Evaluation Research	TVET Pedagogy	Agriculture; plantations; other rural sectors	None	None

TABLE 10. *(Continued.)* **Classification results.**

[92]	Conference	2018	Experiment	Experience Paper	Teaching / Learning Environment	None	Mobile Learning	Computer Programming
[10]	Symposium	2016	No	Other	TVET Pedagogy	None	Distance Education	None
[93]	Conference	2016	Case Study	Evaluation Research	TVET Pedagogy	None	None	None
[94]	Conference	2018	Case Study	Evaluation Research	TVET Pedagogy	None	Massive open online courses (MOOCs)	LMS
[95]	Conference	2014	Case Study	Solution Proposed	TVET Pedagogy	None	None	Artificial Intelligence
[96]	Conference	2015	Experiment	Evaluation Research	TVET Pedagogy	None	None	Recommender System
[97]	Conference	2017	Case Study	Experience Paper	Teachers Training	None	None	None
[98]	Conference	2012	Case Study	Solution Proposed	TVET Pedagogy	None	None	Online Learning
[99]	Conference	2019	Survey	Experience Paper	Curriculum	None	None	Computer Programming
[100]	Conference	2013	Experiment	Solution Proposed	Curriculum	None	None	Online Learning
[101]	Conference	2016	Case Study	Evaluation Research	Assessment	None	None	None
[102]	Conference	2019	Survey	Solution Proposed	TVET Pedagogy	Shipping; ports; fisheries; inland waterways	None	None
[103]	Conference	2019	Case Study	Evaluation Research	Teaching / Learning Environment	None	None	E-Learning
[104]	Conference	2019	Experiment	Evaluation Research	TVET Pedagogy	None	None	Online Learning
[105]	Conference	2019	Case Study	Evaluation Research	Curriculum	None	None	IoT
[106]	Conference	2013	Survey	Solution Proposed	TVET Pedagogy	None	None	None
[107]	Conference	2019	Case Study	Evaluation Research	TVET Pedagogy	None	None	None
[108]	Conference	2019	Experiment	Evaluation Research	Career Guidance	None	None	Data Mining
[109]	Conference	2019	Case Study	Evaluation Research	TVET Pedagogy	None	None	None
[11]	Conference	2015	No	Other	Teaching / Learning Environment	None	None	None
[110]	Conference	2012	Case Study	Evaluation Research	Teachers Training	None	None	None
[111]	Conference	2014	Survey	Solution Proposed	Teaching / Learning Environment	None	Mobile Learning	None
[112]	Conference	2013	Case Study	Evaluation Research	TVET Pedagogy	None	None	None
[113]	Conference	2012	Case Study	Evaluation Research	TVET Pedagogy	None	Mobile Learning	CAD/CAM
[114]	Book	2019	Case Study	Evaluation Research	TVET Pedagogy	None	None	None
[115]	Book	2013	No	Other	TVET Pedagogy	None	None	None
[116]	Conference	2017	Experiment	Evaluation Research	TVET Pedagogy	None	None	None
[117]	Book	2018	Survey	Evaluation Research	Teaching / Learning Environment	None	None	None
[118]	Journal	2016	Survey	Solution Proposed	Teachers Training	None	None	None
[119]	Journal	2019	Case Study	Experience Paper	TVET Pedagogy	None	None	None
[120]	Book	2018	Case Study	Evaluation Research	TVET Pedagogy	None	Distance Education	None
[121]	Book	2015	Case Study	Experience Paper	TVET Pedagogy	None	Mobile Learning	None
[122]	Journal	2013	Survey	Evaluation Research	Career Guidance	None	None	None
[123]	Journal	2019	Case Study	Evaluation Research	Teachers Training	None	None	None
[124]	Journal	2017	Survey	Evaluation Research	Career Guidance	None	None	None
[125]	Journal	2014	Case Study	Solution Proposed	Teaching / Learning Environment	None	Distance Education	None
[126]	Journal	2015	Case Study	Experience Paper	Teachers Training	None	None	None

TABLE 10. *(Continued.)* **Classification results.**

[127]	Journal	2019	Case Study	Solution Proposed	TVET Pedagogy	None	Augmented Reality / Virtual Reality	Online Learning
[58]	Journal	2019	Case Study	Experience Paper	Teaching / Learning Environment	Mechanical and electrical engineering	None	LMS
[128]	Journal	2011	Experiment	Evaluation Research	TVET Pedagogy	None	None	NanoTechnology
[129]	Journal	2018	Case Study	Solution Proposed	Teachers Training	None	None	None
[130]	Journal	2019	Case Study	Evaluation Research	TVET Pedagogy	None	None	None
[131]	Journal	2018	Case Study	Evaluation Research	Teaching / Learning Environment	None	None	None
[12]	Book	2017	No	Evaluation Research	TVET Pedagogy	None	Blended Learning	None
[132]	Journal	2016	Case Study	Evaluation Research	Teaching / Learning Environment	None	None	None
[13]	Report	2013	No	Other	TVET Pedagogy	None	None	None
[133]	Conference	2011	Survey	Solution Proposed	TVET Pedagogy	None	None	None
[134]	Journal	2020	Survey	Evaluation Research	TVET Pedagogy	None	None	None
[135]	Journal	2013	Case Study	Solution Proposed	TVET Pedagogy	None	None	Online Learning
[136]	Conference	2020	Experiment	Experience Paper	TVET Pedagogy	None	None	Online Learning
[137]	Conference	2020	Case Study	Evaluation Research	TVET Pedagogy	None	None	Internet+Education
[138]	Conference	2020	Case Study	Evaluation Research	Teaching / Learning Environment	None	Massive open online courses (MOOCs)	Artificial Intelligence
[139]	Conference	2020	Case Study	Solution Proposed	Teaching / Learning Environment	None	None	Big Data
[140]	Conference	2020	Experiment	Evaluation Research	Teaching / Learning Environment	None	None	Online Learning
[141]	Journal	2020	Experiment	Solution Proposed	Curriculum	None	None	None
[142]	Journal	2020	Case Study	Evaluation Research	Curriculum	None	None	Cloud Computing
[143]	Conference	2020	Experiment	Evaluation Research	TVET Pedagogy	None	Augmented Reality / Virtual Reality	None
[144]	Conference	2020	Case Study	Experience Paper	TVET Pedagogy	None	Mobile Learning	Internet+Education
[145]	Conference	2020	Case Study	Solution Proposed	TVET Pedagogy	None	None	Big Data
[146]	Conference	2020	Case Study	Evaluation Research	TVET Pedagogy	Transport (including civil aviation; railways; road transport)	None	None
[147]	Conference	2020	No	Experience Paper	TVET Pedagogy	None	None	Web Based Services
[148]	Conference	2020	Survey	Evaluation Research	TVET Pedagogy	None	None	None
[149]	Conference	2020	Experiment	Solution Proposed	Teaching / Learning Environment	None	None	LMS

2. Industrial revolutions 4.0/5.0 technologies/functional areas like AI, robotics, cloud computing, big data, IoT, needs to be introduced in the entire TVET training cycle
3. Latest ICT technology areas like Machine Learning, Simulation, Augmented Reality, Virtual Reality, Interactive Whiteboards, Video Conferencing, 3D Modeling, DevOps, Social Media, and Recommender systems, in all TVET training cycle must be used
4. More industry-specific focus TVET research for technology enablement is needed to produce a quality workforce, according to the current market trends and requirements.
5. TVET Monitoring & evaluation, assessment, career guidance, and curriculum ICT enablement.
6. Currently, TVET training is more focused on a traditional classroom approach. In the current era, virtual education and open education are being practiced on a variety of platforms like COURSERA, Udamy, Edx, MIT open courseware, Microsoft education, Oracle education, and Intel education. There is a need to take similar initiatives in TVET education for TVET training, knowledge sharing, and capacity building of the skilled workforce. Particularly, in the post-COVID-19 pandemic scenario, online/virtual training technologies are extensively being used in all educational streams therefore, these must be practiced, tested, and exercised in TVET education too.
7. In Pakistan, the majority of international labor is hired through the middle tier. This middle tier includes agents,

job promoters, employment agencies, and other limited Government initiatives. There is a need to have proper jobs portals and databank framework to directly integrate employers with employees i.e. TVET graduates. Career guidance and job placement are very less focused found in the SLR.

8. To conduct this study, we have considered all influential factors of Figure 1 TVET training cycle system components/functional areas equally important. Practically, these factors vary therefore these factors need to be further explored in each TVET system component/functional areas of the TVET training cycle.

Finally, our motivation after completing this SLR study is to extend this research and develop a framework using Artificial Intelligence based TVET course recommender system which can recommend TVET courses based on individual personality traits. This research will not only help to produce a smart, skilled workforce but will also help to link personality traits/dimensions with different TVET learning skills.

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