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A Systematic Review of Open-Source Software for Technical and Vocational Education and Training (TVET)

Mohd Lutfi Mohd Raffi[1], Mohd Azlan Mohammad Hussain[1,*], Wan Azani Mustafa[2,3], Muhammad Najmi Ahmad Zabidi[4], Achmad Mardiansyah[5], Kamalularifin Subari[6]

[1] Fakulti Pendidikan Teknikal dan Vokasional, Universiti Pendidikan Sultan Idris (UPSI), 35900 Tanjong Malim, Perak, Malaysia
[2] Faculty of Electrical Engineering & Technology, Campus Pauh Putra, Universiti Malaysia Perlis (UNIMAP), Arau 02000, Perlis, Malaysia
[3] Advanced Computing, Centre of Excellence (CoE), Universiti Malaysia Perlis (UniMAP), Arau 02000, Perlis, Malaysia
[4] End Point Corporation, 215 Park Avenue South, Suite 1916. New York, NY 10003, United States of America
[5] GLC Networks, International Education Centre JI. Adipati Kertabumi No.7, Citarum, Bandung Wetan, Kota Bandung 40115, Indonesia
[6] Fakulti Sains Sosial dan Kemanusiaan Sekolah Pendidikan, Universiti Teknologi Malaysia (UTM), Skudai, 81310 Johor Bahru, Johor, Malaysia

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ABSTRACT

In the era of Industry 4.0, software is essential for connecting technologies, creating smart systems, and driving innovation across industries. There are several challenges and limitations related to software in Technical and Vocational Education and Training (TVET), such as software cost, software piracy, and limited modification access to the software. This demonstrates the demand for new approaches that may deal with these issues and offer alternatives by using the open-source software. The paper aims to explore on the utilization and impact of Open-Source Software (OSS) in TVET based on three main themes: (1) hardware compatibility using OSS, (2) teaching and learning aids using OSS, and (3) online learning practice using OSS. Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach, the research, based on 21 articles selected from Scopus and Eric databases, reveals that OSS is compatible with hardware used in TVET programs, offers diverse teaching and learning aids, and is suitable for online learning environment. These findings underscore OSS's potential as an alternative in meeting TVET requirements, fostering dynamic learning environments, and improving pedagogical approaches, accessibility, and cost-effectiveness in TVET institutions.

1. Introduction

The pace of change is remarkable in the dynamic context of Industry 4.0, marked by the seamless integration of technology and manufacturing. This era is characterized by the pervasive influence of digitalization and automation, fundamentally altering how industries function. Central to this transformation is the pivotal role of software, as emphasized by Wachs *et al.,* [1]; Wadood *et al.,* [2]; and Nakagawa *et al.,* [3] in their papers. Software serves as the linchpin that orchestrates this

* *Corresponding author.*
E-mail address: azlan_hussain@ftv.upsi.edu.my

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symphony of innovation. It enables machines to communicate, collect, and analyse data in real-time and make informed decisions.

Due to the expanding significance of digital technologies in the field of education, especially in Technical and Vocational Education and Training (TVET), software utilization has also become crucial, as highlighted by Antonietti *et al.,* [4] and Fadel *et al.,* [5] studies. TVET's primary goal is to equip individuals with practical skills for the workforce. Furthermore, incorporating software tools into TVET programs expands on this aim by facilitating hands-on learning experiences and bridging the theory-application gap. According to studies, software-enabled TVET promotes a more profound comprehension of technical ideas and improves students' preparation for real-life challenges, as highlighted by Ismail *et al.,* [6], Nawi *et al.,* [7], Hashim *et al.,* [8] and Mtshali *et al.,* [9] in their papers.

There are several challenges and limitations related to software in TVET. One of the issues is the software cost to be employed in TVET programs, as highlighted in previous studies by Zajc *et al.,* [10] and Peters *et al.,* [11]. In the market, various pricing plans for subscription services can be discovered. The subscription service price has four main parts based on conclusions from Fruchter *et al.,* [12], which are:

i. the activation or installation fee, which requires a one-time payment when customer start using the service
ii. a subscription fee, which is regular payment to keep using the service
iii. a usage fee paid for extra feature in addition to the primary service
iv. an exit or cancellation fee paid for stop using the service before the agreed time.

Based on findings from Sulistyo *et al.,* [13], the TVET program already required substantial expenditures for equipment needed in practical sessions; the additional cost for software will impact the program's implementation.

Based on previous studies discussed in Sagheb-Tehrani *et al.,* [14], Rachmatdia *et al.,* [15], Herjanto *et al.,* [16], and Kigerl [17], the inability to afford software can lead to software piracy. Software piracy is described as the unauthorized use or duplication of software; in some ways, it is similar to stealing. In addition, the education sector is partly responsible for the piracy problem. This aligned with the survey results by Miraja *et al.,* [18] finds that college students are the most likely to use pirated software. They also added that this affects not just the software manufacturer, who would incur significant sales losses, but also educational institutions, who will face indirect consequences, whether economic or ethical.

Furthermore, research by Prokakis [19] explained that proprietary software providing a standardized package that employs a one-size-fits-all approach causes software features to be poorly utilized while at the same time leaving out crucial features that are specific to the needs of the user. The ability to customize and modify the software to meet users' particular requirements allows for more efficient fulfilment of their software needs. This highlights the need for new ideas to address these issues and propose alternatives to the use of proprietary software in TVET through the implementation of open source, as suggested by Lotfi *et al.,* [20], Peters *et al.,* [11] and Ariza *et al.,* [21]. The taxonomy of software explained by Wei [22] can be referred to in Figure 1.

Open-source software (OSS) is available for anyone to view, use, edit, and distribute without restriction. OSS frequently touts transparency, security, and cost-effectiveness, making it an appealing option for a variety of applications, including education and programming, based on previous studies from Call *et al.,* [23], Zajc *et al.,* [10], and Alnassar [24]. Moreover, the capability of OSS that enables the user to modify the software empowers TVET educators to tailor the software to the specific needs of TVET programs, as mentioned in the findings of Nehra *et al.,* [25]. However,

several essential challenges require attention to fully exploit the potential of OSS in this field. Firstly, the hardware compatibility issue when integrating OSS solutions into the TVET environment poses a significant barrier, as discussed by Swarts [26] in his paper. Ensuring seamless interaction between OSS and various hardware configurations is imperative to achieving optimal educational outcomes. Second, the effectiveness of OSS is to be used as teaching and learning aids. The article explores how OSS can provide equal, if not superior, teaching and learning support in TVET while assessing the potential advantages and disadvantages. Finally, the suitability of OSS tools and platforms for online learning must be studied in detail. Understanding how OSS can facilitate and enhance online learning practices in TVET contexts is essential for success, especially in the post-pandemic era.

The challenges and constraints associated with proprietary software, including cost, piracy, and limited modification access, emphasize the urgent need for alternative solutions. While Industry 4.0 underscores the significance of software in linking technologies and propelling innovation, there needs to be more comprehensive studies investigating the specific application and advantages of Open-Source Software (OSS) in the context of Technical and Vocational Education and Training (TVET). The importance of this research lies in highlighting the potential of OSS as a substitute to address TVET requirements, promote dynamic learning environments, and enhance pedagogical methods, as well as accessibility and cost-effectiveness in TVET institutions. Thus, this paper aims to delve into the utilization and impact of OSS in TVET, focusing on three primary themes:

i. hardware compatibility through OSS
ii. utilization of OSS in teaching and learning aids
iii. the practice of online learning facilitated by OSS.

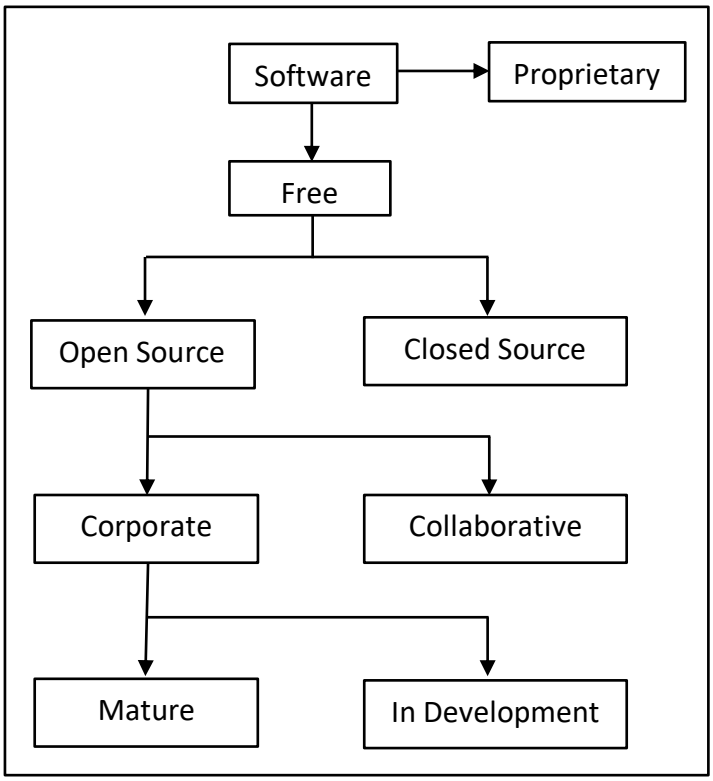

Fig. 1. The software taxonomy by Wei [22]

2. Methodology

In elucidating the methodology employed in this study, we navigate the intricate path of investigating the utilization and impact of Open-Source Software (OSS) within the realm of Technical and Vocational Education and Training (TVET). Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique suggested by Moher *et al.,* [27], a widely accepted standard for systematic literature reviews, our study strategically selects and analyses relevant articles from Scopus and Eric databases. However, it is acknowledged that no database, including Scopus and Eric, is exhaustive. This section meticulously unveils the systematic steps involved in four primary sub-sections: identification, screening, eligibility, and data abstraction. The investigation focuses on three main areas:

i. assessing how OSS ensures compatibility with hardware
ii. exploring the support provided by OSS in teaching and learning aids
iii. examining the incorporation of OSS in online learning practices.

Through a robust methodology, this research aims to provide valuable insights into the effectiveness of OSS as a transformative factor in addressing challenges and improving educational practices within the TVET landscape.

2.1 Identification

The three fundamental stages of the systematic review procedure were used to narrow down the several appropriate articles for this study. The identification of keywords and the search for related terms utilizing thesaurus, dictionaries, encyclopaedias, and prior research encapsulate the first process. After choosing all relevant phrases, search strings for the Scopus and Eric databases were developed (see Table 1). As a result, 727 papers were discovered in both databases during the first stage of the systematic review process.

Table 1
The search strings (Export date: 20 September 2023)

Scopus	TITLE-ABS-KEY ((“open source software” OR “open-source software”) AND (“technical and vocational education and training” OR vet OR “engineering education” OR “technology education”)) AND (LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (PUBSTAGE, “final”)) AND (LIMIT-TO (EXACT KEYWORD, “Open Source Software”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (LANGUAGE, “English”))
ERIC	(“open source software” OR “open-source software”) AND (“technical and vocational education and training” OR “tvet” OR “engineering education” OR “technology education”) pubyearmin:2020 pubyearmax:2023

2.2 Screening

Duplicate work should not be considered in the initial screening phase. Based on various inclusion and exclusion criteria established by the researchers (see Table 2), 682 papers were excluded in the first phase, while no duplicate articles were evaluated in the second phase. Since literature (research articles) is the primary source of practical knowledge, it was the first criterion. Additionally, the current study did not include publications in the form of systematic reviews, reviews, meta-analyses, meta-syntheses, book series, books, chapters, or conference proceedings. Only English-language

studies were included in the review. The selection of a four-year term (2020-2023) for this study is intricately tied to the evolving landscape of online learning, which is one of the objectives of this study and has gained heightened significance in the post-pandemic educational era. As a result, 45 publications were selected based on predefined criteria.

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline / Years	2020-2023	<2020
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

2.3 Eligibility

A total of 45 articles have been prepared for the third step, known as eligibility. To ensure the inclusion criteria were satisfied and the papers fit within the current study, the current research aims, the titles, and the main content of each article were carefully reviewed. As a result, 24 articles were eliminated as they were not included in the complete text, the title needed to be more suitable, or the abstract required to match the aim of the study as supported by empirical evidence. In the end, there are 21 articles available for review.

2.4 Data Abstraction and Analysis

Integrative analysis, which was used to analyse and synthesize a variety of research designs (quantitative, qualitative, and mixed techniques), was one of the assessment tools utilized in this study—the competence research aimed to identify pertinent themes and subtopics. Data gathering was the first phase of the theme's development. Figure 2 illustrates how the authors have thoroughly examined through a collection of 21 articles for findings or information relevant to the topics of the current investigation using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique suggested by Moher *et al.,* [27].

The articles selected were carefully reviewed for several reasons. These articles align with the research's scope and objectives, showcasing robust methodology and relevance to the chosen themes. Each article significantly contributes to understanding the subject, offering diverse perspectives and approaches with a clear emphasis on quality over quantity. Consequently, the author collaborated with other co-authors to develop themes based on the collected remarks to ensure relevance for this study. Throughout the data analysis process, a written record was kept to note any analyses, opinions, riddles, or other ideas related to the interpretation of the data. Subsequently, the authors compared the findings to identify inconsistencies in the theme design procedure. It should be mentioned that the authors will discuss it together if there are disagreements in the themes. The final generated themes were revised to ensure consistency. The analysis selection was conducted by TVET expert Azlan Hussain and computer science expert Wan Azani Mustafa to determine the validity of the problem. This is to ensure clarity, significance, and relation to the main idea of the study.

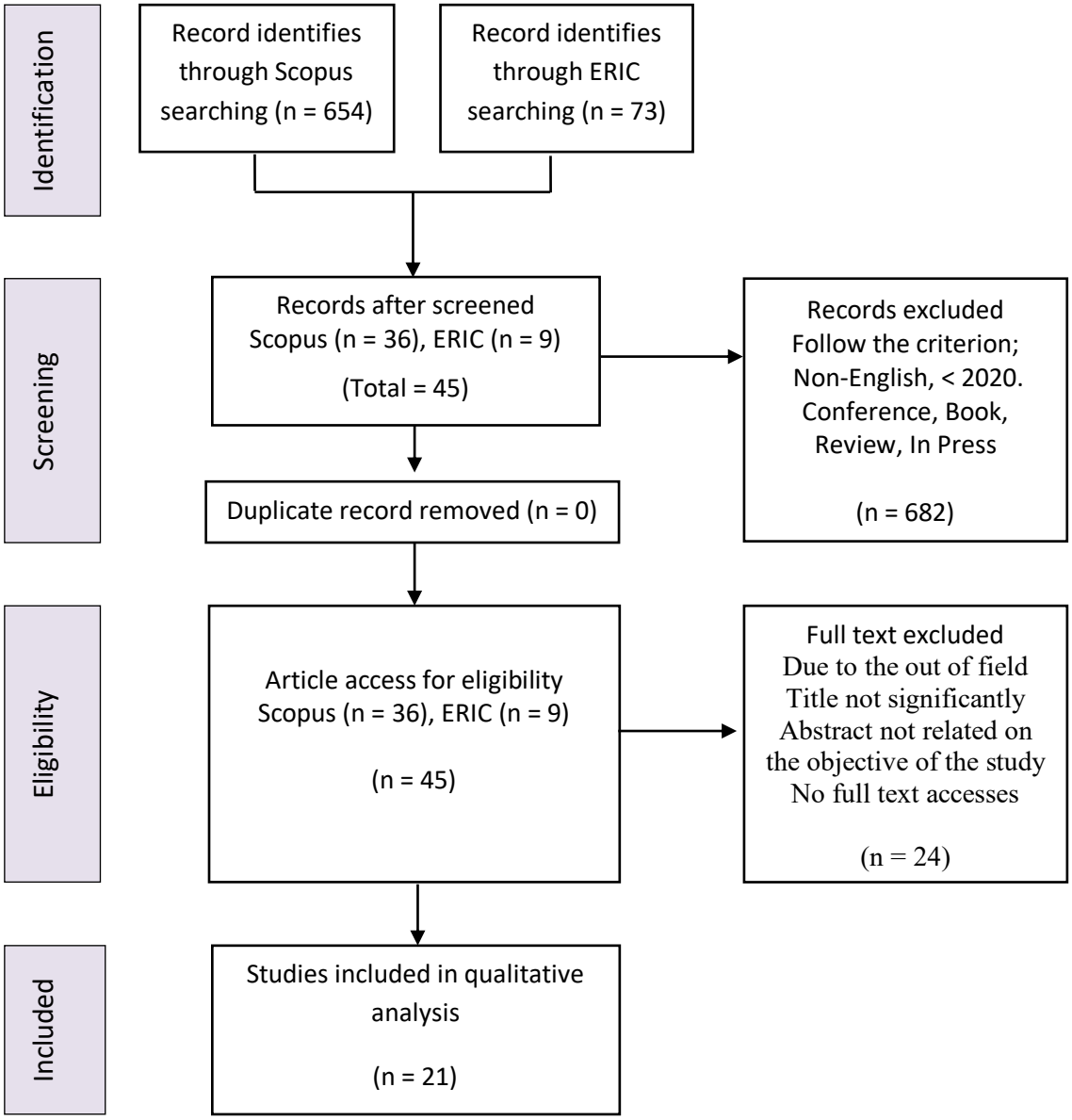

Fig. 2. Flow diagram of the proposed searching study as suggested by Moher *et al.,* [27]

3. Results

OSS enables users to modify and distribute and offers a low-cost alternative solution for TVET programs. Based on the search techniques, 21 articles related and relevant to OSS for TVET were selected. All articles are categorized into three main themes, which are hardware compatibility with OSS (eight articles), teaching and learning aids using OSS (seven articles), and online learning practice using OSS (six articles).

3.1 Hardware Compatibility with OSS

Any software is unable to be used in the absence of hardware or a device. Therefore, the compatibility of OSS with hardware is critical to ensure it can be implemented in TVET programs.

Eight recent papers discuss hardware compatibility with OSS and demonstrate encouraging results (refer to Table 3).

Table 3
Summary of compatible hardware with OSS use in TVET programs

Reference	Document title	Compatible hardware with OSS	Results and advantages
[11]	Peters, Andrés A., Francisco J. Vargas, Cristóbal Garrido, Cristóbal Andrade, and Felipe Villenas. "Pl-toon: A low-cost experimental platform for teaching and research on decentralized cooperative control." *Sensors* 21, no. 6 (2021): 2072	Pl-toon, a low-cost multi-agent system experimental platform utilized for both education and research, was described in this article. It is an Arduino-based project with other inexpensive components programmed using OSS that aims to improve motor control learning.	The platform's abilities are demonstrated by the experimental findings in some of the instructional activities.
[21]	Ariza, Jonathan Álvarez, and Christian Nomesqui Galvis. "RaspyControl Lab: A fully open-source and real-time remote laboratory for education in automatic control systems using Raspberry Pi and Python." *HardwareX* 13 (2023): e00396.	This study presents a low-cost, open-source remote lab using Raspberry Pi and Python. It focuses on teaching automatic control systems. The lab is suitable for teaching Python control activities since it features an intuitive online interface and real-time video.	Students, educators, and stakeholders can use the Raspy Lab's completely functional, cost-effective, and open-source remote laboratory.
[28]	Rodriguez-Sanchez, Maria Cristina, Pinaki Chakraborty, and Norberto Malpica. "International collaborative projects on digital electronic systems using open-source tools." *Computer Applications in Engineering Education* 28, no. 4 (2020): 792-802.	The initiatives covered in this article were automated irrigation systems, automatic car washing, assisted living for the elderly, and smart lighting. By utilizing hardware based on Arduino, the students put their solutions into practice.	The students reported that they had no trouble utilizing the tools or talking with teammates from other countries in a survey that was conducted at the conclusion of the study. They also said that they had an overall pleasant learning experience. As a result, students were more motivated and received higher grades on average.
[29]	Woo, Winnie, William Richards, John Selker, and Chet Udell. "WeatherChimes: An open IoT weather station and data sonification system." *HardwareX* 13 (2023): e00402.	WeatherChimes, a low-cost OSS and hardware package, provides direct access to real-world environmental sensor data such as light, temperature, relative humidity, and soil moisture from any location with a Wi-Fi Internet connection.	The system's sensor and online data logging capability has been validated in lab and field tests.
[30]	Mutlu, Ahu Komec, Ulgen Mert Tugsal, and Ahmet Anil Dindar. "Utilizing an Arduino-Based Accelerometer in Civil	An Arduino-based accelerometer and related software tools were developed to gather and display structure vibration data in order to comprehend seismic safety best practices. Python, an open-source	The gadget based on Adruino has the ability to collect data, which can then be recorded, saved, presented, and
Reference	Document title	Compatible hardware with OSS	Results and advantages
	Engineering Applications in Undergraduate Education." *Seismological Research Letters* 93, no. 2A (2022): 1037-1045.	programming language, and Arduino are both used in this tool.	filtered using the Python programming language.

[31]	Garg, Ankit, Yuanxu Huang, Huang He, Xilong Huang, Peng Lin, Kanishk Kalra, Guoxiong Mei, Vaibhav Khandare, and Lovepreet Singh. "Geotechnical engineering educational modules demonstrating measurement and regulation of soil moisture." *Computer Applications in Engineering Education* 30, no. 3 (2022): 973-985	This study offers fresh knowledge about software (LabVIEW and Android studio) and hardware (Time-Domain Reflectance (TDR) probe), Arduino UNO, and water flow measurement), followed by the completion of group projects by the students.	It was discovered that student satisfaction and understanding increased significantly across subjects (electronics and optics).
[32]	Ueyama, Yuki, Takashi Sago, Toru Kurihara, and Masanori Harada. "An Inexpensive Autonomous Mobile Robot for Undergraduate Education: Integration of Arduino and Hokuyo Laser Range Finders." *IEEE Access* 10 (2022): 79029-79040.	The integration of the economical Hokuyo URG-04LX-UG01 laser range finder with an Arduino microcontroller in a Science, Technology, Technology, and Mathematics (STEM) curriculum for mechanical engineering students is explored in this article. Due to its open-source nature and low price, Arduino is perfect for educational applications.	Based on the findings of the questionnaire administered to the students as participants after the course, the course boosted their knowledge, motivation, interest, and satisfaction.
[33]	Jean, Devin, Brian Broll, Gordon Stein, and Ákos Lédeczi. "Utilizing Smartphones for Approachable IoT Education in K-12." *Sensors* 22, no. 24 (2022): 9778.	In this article, PhoneIoT, a mobile application that transforms smartphones and tablets into Internet of Things (IoT) devices, is highlighted. It facilitates beginners in learning distributed computing and networked sensors. It connects with NetsBlox, a block-based programming environment that is open source and enables engaging projects.	This method enables students to develop rather complex distributed projects, such as tracking their movements on an interactive Google Maps platform or playing a game using their phone as a controller.

3.2 Teaching and Learning Aids using OSS

Using software allows teachers to deliver more effectively while making learning more entertaining and influencing student success. Besides, using OSS helps reduce software licensing costs while enabling teachers to customize the software to fit the curriculum. Furthermore, the usage of OSS can help reduce piracy in TVET programs. Seven papers discuss teaching and learning aids using OSS and exhibit encouraging results (Table 4).

Table 4
Summary of teaching and learning aids using OSS in TVET programs

Reference	Document title	Teaching and learning aids using OSS	Results and advantages
[34]	Laayati, Oussama, Hicham El Hadraoui, Nasr Guennoui, Mostafa Bouzi, and Ahmed Chebak. "Smart Energy Management System: Design of a Smart Grid Test Bench for Educational Purposes." *Energies* 15, no. 7 (2022): 2702.	This article discusses an educational test bench for microgrids, designed for students and researchers, incorporating diverse energy sources like wind, solar, and hydrogen and storage systems. Users can monitor components using OSS, test energy management solutions with machine learning, and optimize algorithms.	Students can comprehend smart grid aspects such as fault classification, energy forecasting, energy optimization, and production, transmission, and consumption fundamentals.
[35]	Čisar, Petar, Peter Odry, Sanja Maravić Čisar, and Gordana Stankov. "Teaching spread spectrum in the course telecommunication systems using octave." *Computer Applications in Engineering Education* 28, no. 2 (2020): 367-383.	This paper explains the spread-spectrum technique in telecommunications for better student comprehension. Octave, the OSS, was used to solve practical examples and computational tasks.	The study's findings lead us to conclude that software such as Octave should be used to supplement standard teaching and learning methods in courses such as Telecommunication Systems.
[36]	Yue, Haosong, Jinyu Miao, Jinqing Zhang, Changbo Fan, and Dong Xu. "Simulation for senior undergraduate education of robot engineering based on Webots." *Computer Applications in Engineering Education* 29, no. 5 (2021): 1176-1190.	This paper introduces a simulation framework using OSS, Webots. It focuses on a virtual quadruped robot in the curriculum. Students design the robot's structure, choose suitable drivers, analyse leg kinematics and workspace, and study terrain recognition as well as motion planning.	The simulation findings suggest that multiple robot strategies can be tested in the suggested simulation framework. Teaching practice and student responses demonstrate their promotion of comprehension of robot theory.
[37]	Rabello-Mestre, Andre, and Felipe Otondo. "Creative Dispositions: Teaching for Creativity in Engineering Education." International Journal of Engineering Education 37, no. 4 (2021): 915-924.	This course seeks to introduce engineering students to applied musical creativity. Designing a semi-automated interactive digital tool utilizing Pure Data, an open-source visual programming tool, is the final assignment provided to the student.	Pure Data has served as the foundation for several projects, including a prototyping language and a sound engine. It also can be utilized in networked performance.
[38]	Ghosh, Sunavo, Arghya Nandi, and Sumanta Neogy. "Undergraduate dynamics using the logic of multibody dynamics—Indigenous code and an open-source software." *Computer Applications in Engineering Education* 30, no. 1 (2022): 5-30.	This article uses Phyton Dynamics (PyDy) an open-source multibody dynamics software, to provide a more affordable option. It encourages students to learn about dynamics and receive training in multibody dynamics. With a basic understanding, students can create simple problem-solving programs using Python, even before using such packages.	Feedback from students concerning their willingness to use the package and their impression of its effectiveness as a beneficial tool in learning motivation were both overwhelmingly favourable.

[39]	Došen, Dario, Marinko Stojkov, Damir Šljivac, and Matej Žnidarec. "System Control and Data Acquisition of University Photovoltaic Power Plant." *Tehnički vjesnik* 29, no. 4 (2022): 1310-1315.	This article focuses on the design of a photovoltaic power plant Supervisory Control and Data Acquisition (SCADA) system, as well as its configuration and connection to a data storage server. Access is possible via an Android device or PC. Continuous measurements of photovoltaic parameters and meteorological conditions are collected and stored locally and remotely, with data displayed on a web server platform.	The designed SCADA described in this paper is a custom adaptive open-source system that enables the long-term operation of power plants and their components.
[40]	Singh, Jasmine, Viranga Perera, Alejandra J. Magana, Brittany Newell, Jin Wei-Kocsis, Ying Ying Seah, Greg J. Strimel, and Charles Xie. "Using machine learning to predict engineering technology students' success with computer-aided design." *Computer Applications in Engineering Education* 30, no. 3 (2022): 852-862.	Students' performance in creating net-zero energy homes was predicted using data from students using the OSS Computer-aided design (CAD) program Aladdin.	The data suggested over 60% accuracy. This suggests that Aladdin can provide valuable feedback to students midway through their designs.

3.3 Online Learning Practice using OSS

Online learning has gained even greater prominence in the post-pandemic educational landscape. The pandemic situation forced educational institutions around the world to swiftly adapt to remote learning as a means of ensuring continuity in education. As a result, many educators and students became more familiar with online learning platforms and the digital tools that support them. The pandemic accelerated the adoption of online learning. Hence, its significance persists in the post-pandemic era. Selected articles (six articles) related to online learning using open source have proven their value, offering affordable, personalized, and adaptable solutions for education (refer to Table 5).

Table 5
Summary of online learning practice using OSS in TVET programs

Reference	Document title	Online learning practice using OSS	Results and advantages
[41]	Shen, Yingjie. "Application of Internet of Things in Online Teaching of Adult Education Based on Android Voice Assistant." *Mobile Information Systems* 2022 (2022).	This article covers an online training program for higher education for adults that makes use of Android technology and mobile device capabilities. A user-friendly interface is produced by applying the use of open-source code in the creation of Android applications.	The outcomes demonstrate that the system's functionality can be effectively realized, that operation efficiency is high and that individualized course design is possible.

[42]	Beg, Azam, Mouza Alhemeiri, and Ajmal Beg. "A tool for facilitating the automated assessment of engineering/science courses." International Journal of Electrical Engineering & Education 60, no. 3 (2023): 313-325.	In this article, QAgen, an OSS program that automatically generates questions and answers on a range of subjects, is introduced. These questions can be used for LMS-based or LMS-free assessments, making them adaptable and promoting both conventional courses and Massive Open Online Courses (MOOC)	Survey question sets were made for three different courses in order to assess QAgen's efficacy. Students reported that the questions helped them prepare for exams and practical assessments in surveys they participated in.
[43]	Bart, Austin Cory, Javier Tibau, Dennis Kafura, Clifford A. Shaffer, and Eli Tilevich. "Design and evaluation of a block-based environment with a data science context." *IEEE Transactions on Emerging Topics in Computing* 8, no. 1 (2017): 182-192.	For beginners in computer science, BlockPy is a free, open-source, web-based programming environment. Learners receive guided feedback as they solve puzzles in a block-based environment.	BlockPy is a stand-alone software that completely complies with the most recent standards for learning tool interoperability, enabling teachers to seamlessly incorporate the environment into Learning Management Systems (LMS).
[44]	Lavayssière, Camille, Benoît Larroque, and Franck Luthon. "Laborem Box: A scalable and open-source platform to design remote lab experiments in electronics." *HardwareX* 11 (2022): e00301.	The Laborem project enables students to conduct electronic lab experiments remotely. It began with proprietary software in 2011, then migrated to use OSS, PyScada, and an open-source Laborem Box in 2017.	The Laborem Box connects interchangeable circuit boards for flexible teaching while a user-friendly software interface is provided for students.
[23]	Call, Madison W., Erik Fox, and Gina Sprint. "Gamifying software engineering tools to motivate computer science students to start and finish programming assignments earlier." *IEEE Transactions on Education* 64, no. 4 (2021): 423-431.	An open-source game system called Leaderboard was created to motivate students to start and finish homework earlier. Moodle learning management system, a build server, and GitHub Classroom are used for system automation.	Students who utilized the Leaderboard did not begin assignments significantly earlier; nevertheless, they completed their tasks earlier, produced code more frequently, and passed more unit tests. The findings demonstrate that the Leaderboard motivates students and causes them to appreciate completing the unit test.
[45]	Lane, David C., and Claire Goode. "Open For All: The OERu's Next Generation Digital Learning Ecosystem." *International Review of Research in Open and Distributed Learning* 22, no. 4 (2021): 146-163.	Open Educational Resources (OERu) Foundation and 36 publicly supported universities collaborated to develop an OSS infrastructure known as the "Next-Generation Digital Learning Ecosystem" (NGDLE).	All OERu services are hosted on a free OSS infrastructure, offering organizations adopting any of these services great benefits and chances to improve their educational institutions at minimal expense.

4. Conclusions

Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach for this study, 21 articles were selected from Scopus and Eric databases. The findings reveal that open-source software (OSS) is compatible with hardware used in Technical and Vocational Education and Training (TVET) programs, offers diverse teaching and learning aids, and is suitable for online learning environments. Based on eight selected articles, it is demonstrated that OSS is compatible with hardware devices such as Arduino and Raspberry Pi. Arduino is well-suited for

simple, real-time control projects, especially those with power constraints. At the same time, Raspberry Pi is more versatile, offering greater processing power and connectivity, making it suitable for a broader range of applications, including those requiring a full-fledged computer.

Furthermore, these devices are easy to discover and can have strong support and training resources from the OSS community. This compatibility opens up exciting hands-on learning and experimentation possibilities, particularly in computer science, robotics, and electronics. Therefore, educators can leverage these hardware platforms to create interactive and practical learning experiences for their students.

The research findings also clearly indicate that OSS is suitable and highly effective as a teaching and learning aid within the context of TVET programs. TVET programs are known for their practical and hands-on approach to education, emphasizing skill development and real-world application. Note that OSS aligns exceptionally well with these goals for several compelling reasons. Seven articles emphasize that open-source software (OSS), such as Octave, Webots, Pure Data, Drop Project, PyDy, and SCADA (refer to Table 4), can be a viable alternative to proprietary software. The studies delve into various applications, including testing microgrid energy sources, teaching spread-spectrum in telecom, simulating robots, designing music creativity tools, teaching dynamics, monitoring solar power plants with a SCADA system, and predicting net-zero home designs using the OSS CAD program Aladdin. These investigations underscore OSS's adaptability across diverse educational domains, simplifying complex subjects and enhancing accessibility for students.

Finally, the research indicates that OSS tools and platforms for online learning can be used in TVET programs. Six articles explored various aspects of online learning, incorporating open-source software (OSS) to enhance educational experiences, especially in TVET. One article focuses on an Android-based online training program for adults, utilizing OSS to create a user-friendly interface. Another introduces QAgen, an OSS program generating adaptive questions for assessments in both traditional and Massive Open Online Courses (MOOCs). For beginners in computer science, BlockPy offers a free, web-based programming environment with guided feedback. The Laborem project enables remote electronic lab experiments, transitioning to OSS in 2017. Leaderboard, an OSS game system, motivates students to complete homework earlier using Moodle, a build server, and GitHub Classroom. Lastly, a collaboration between the Open Educational Resources Foundation and 36 universities results in the Next-Generation Digital Learning Ecosystem (NGDLE), an OSS infrastructure to enhance the digital learning ecosystem. Collectively, these initiatives showcase OSS's versatility in transforming and motivating online learning across different educational domains.

While this study sheds light on the compatibility and effectiveness of open-source software (OSS) in Technical and Vocational Education and Training (TVET) programs, it is essential to acknowledge its limitations. The selection of articles from Scopus and Eric databases, although systematic, may introduce bias and limit the generalizability of findings. The focus on specific OSS tools may restrict the broader applicability of results, and the study might cover only some areas within TVET. Relying on available article information and the dynamic nature of technology could impact the study's completeness and relevance. Additionally, the evolving landscape of OSS tools may have seen new developments since the selected articles were published. These limitations emphasize the need for caution in interpreting the findings and suggest avenues for future research to explore a broader spectrum of OSS applications in TVET programs.

Several recommendations can be considered to enhance and expand future research. Firstly, there is a need for more in-depth studies on the compatibility of open-source software (OSS) with evolving hardware technologies in Technical and Vocational Education and Training (TVET). This involves exploring advanced hardware components beyond Arduino and Raspberry Pi and conducting comparative analyses to understand the optimal combinations for diverse TVET applications.

Secondly, to broaden the application of OSS, researchers should explore additional tools and platforms catering to specific TVET domains not covered in the current study. Collaboration with TVET educators and industry professionals is crucial to tailor OSS applications to address specific skill gaps, ensuring practical relevance in real-world scenarios. Lastly, future studies should incorporate longitudinal assessments to track the sustained impact of OSS integration in TVET programs, involving qualitative methods to understand better the lasting effects on students' skill development, employment outcomes, and contributions to their respective industries.

The study's practical implications also highlight the importance of continuous educator training and support for effective OSS integration in TVET teaching. Curriculum designers are encouraged to seamlessly incorporate OSS into TVET programs, aligning with the hands-on nature of education. Collaborations between TVET institutions and industry partners are essential to align OSS applications with industry demands, enhancing graduates' employability in technology-driven sectors. It is imperative to investigate further to ascertain the endurance and development of open-source initiatives in TVET over time. In conclusion, this literature assessment emphasizes the potential of OSS to enhance TVET and underscores the importance of continued exploration in future studies.

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