The Evolution of Quality Education: Impacts and Challenges of Using Open Educational Resources (OER) and Open Educational Practices (OEP) in the Conceive - Design - Implement - Operate (CDIO) Framework

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Abstract – **This Research examines how open educational resources (OER) and open educational practices (OEP) provide fair access to high-quality education. Using qualitative research, the author evaluates university formal education OER and OEP deployment and outcomes. This research found that OER, CDIO (Conceive – Design – Implement – Operate), and single-boar computer (SBC) learning media increase curricular content and instruction. Open education encourages education community cooperation and interaction. However, copyright, quality assurance, and curricular integration persist. This Research also explores the CDIO framework to promote OER and OEP, suggesting that these four elements may alter education.**

***Keywords* – SBC, OER, OEP, CDIO, Qualitative.**

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1. Introduction

A single-board computer (SBC) will be used in STEM education for chemistry teachers in the future by taking an engineering approach using a single board computer [1]. Previous research used SBC as a monitoring system in Industry 4.0 [2], [3], which means SBC produces power efficiency and mobilization while being affordable [4].

A SBC is a self-contained computing device that is constructed on a solitary circuit board, including essential components such as a microprocessor, memory, Input/Output (I/O) interfaces, and other requisite elements to enable its functionality as a fully operational computer [5], [6]. However, this definition must fully cover the critical differences between SBC and other platforms: The factors that need to be considered are the accessibility of general-purpose input/output (I/O) ports, the level of power consumption, and the associated costs. SBCs fall between controller boards and PCs in this regard. Most SBC today use ARM processors, such as smartphones, compared to Intel/AMD chips used in the PC market [7].

The Raspberry Pi is a market-leading SBC, with sales of over one million units within the first year. It is also the third best-selling general-purpose computer of all time. There is a limited range of SBC platforms, each with advantages and disadvantages [8]. Manufacturers also recognize the need for stability in product availability, such as the production guarantee offered by the Raspberry Pi 3 until January 2023.

The main advantage of SBC is their low price, which allows children to buy their own and relieves parents.

Projects that require multiple SBC are also affordable, and the general public has come to regard SBC as standard building blocks in projects supported by examples, documentation, and voluminous software [9].

SBC are also used when standard PCs are unsuitable [10]. The low power consumption of SBC also benefits wireless sensor networks and traditional data centers with up to 23x reduction in power consumption [11].

Recent developments in SBC include an increase in peripherals included on the board. For example, Up Squared has a Pentium processor and an on-board FPGA. While these may have a higher price [3], the more powerful peripherals will likely be more affordable. One challenge that SBC still need is storage limitations due to the lack of high-speed interconnects, but some other SBC have overcome this by providing SATA ports to connect standard HDDs and SSDs directly [12].

E-learning, or electronic learning, uses telecommunications technology to provide education and training [13]. The main advantage of e-learning is the flexibility of time and space, as these restrictions do not limit the interaction between learners and instructors or between learners [14]. The demand for e-learning has increased among businesses and higher education institutions, with notable examples such as MIT's efforts to provide their courses online. Although the e-learning market continues to grow, there are still failures in implementing these systems [15].

Previous research has identified factors that influence user satisfaction in e-learning. These factors include student characteristics, teachers, subjects, technology, system design, and environmental factors [16]. However, these suggestions from researchers may not be practical as so many factors must be considered. Therefore, this study aims to identify important factors that can holistically ensure successful e-Learning design and operation and provide e-Learning management guidelines. The results of this study can assist institutions in adopting e-learning technology by addressing potential barriers that can reduce the risk of failure.

E-Learning is a web-based system that eliminates time and geographical limitations in learning. However, its implementation requires sufficient human resources, time, and materials [17]. Research in psychology and information systems has identified various variables associated with e-learning, including the technology acceptance model and the expectation and confirmation model [18]. Within the six dimensions previously identified, thirteen factors influence user satisfaction in e-Learning.

These factors include students' attitudes and abilities towards technology, instructors' responses and attitudes towards e-learning, course flexibility and quality, technology and the Internet use [19], [20].

Open educational resources (OER) refer to educational materials utilized for teaching, learning, and research purposes, either in the public domain or licensed in a manner that grants unrestricted permission for their utilization and distribution by all individuals. Most current academic studies on OER implementation in higher education primarily concentrate on two aspects: the utilization of OER by students and the perceptions of faculty members about the adoption and integration of OER [21], [22]

However, it remains to be seen how the use of OER can affect overall educational practices, especially when instructors involve students in utilizing and designing OER [23], [24]. Open educational practices (OEP) and open pedagogy have the potential to facilitate student autonomy, foster social constructivist learning, and promote the exchange of knowledge. Students value open pedagogical approaches due to their engaging nature, personalized learning experiences, and relevance. Furthermore, the engagement of students in the curation and revision of OER has the potential to enhance their understanding of open access, open licenses, and the socioeconomic implications associated with OER [25].

However, some challenges may be faced in implementing OEP and engaging students in CDIO-based learning. Some students may experience difficulties carrying out renewable tasks requiring deep thinking and higher-order cognitive tasks [26], [27]. Other challenges include lack of structure or guidance from instructors, difficulties with technical and information literacy skills, concerns about grading assignments, difficulties working in groups, and concerns about publicly publishing work.

In conclusion, OEP and using OER have great potential to enhance student learning and skill development. Further investigation is necessary to comprehend the impact of student engagement in the curation and creation of OER for a worldwide audience on students' attitudes, motivation, skill acquisition, and overall educational attainment [28].

OER has gained many advantages, such as facilitating knowledge sharing, reducing learning costs, and ensuring inclusive learning [29], [30]. Universities around the world are beginning to adopt OER in their educational practices. However, researchers have shifted focus from content-centered approaches to OEP that encourage collaboration between learners and teachers to create and share knowledge [31], [32]. OEP is considered a pedagogy that supports OER.

OEP has become a trend in information and communication technology-based education. OEP expands access to high-quality educational content by creating and utilizing OER innovatively and engages learners in the knowledge-creation process. OEP also helps achieve accessible and lifelong learning [33]. The OEP architecture comprises five key components: OER, open teaching practices, open collaboration, open assessment methods, and supporting technology.

The COVID-19 pandemic has necessitated the rapid implementation of online learning in universities worldwide, amplifying the significance of open education and OEP [34], [35]. Some universities have implemented OEP during the pandemic to sustain learning. Although OEP is a new research theme, it is expected to continue to grow. However, critical questions still need to be answered regarding implementing OEP in higher education. Researches indicate a requirement for additional elucidation about using OEP within higher education pedagogy [36], [37], [38]. The provision of such information would enhance the ability of educators in higher education to adopt OEP effectively. Therefore, further research is needed to answer these questions and strengthen the implementation of OEP in education.

The CDIO (Conceive - Design - Implement - Operate) initiative started at MIT in the late 1990s as a response to engineering education focusing more on science than engineering practice. Engineering education was separated from engineering practice, resulting in a lack of professional engineering experience and weakly associated educational values [39], [40]. Industry and accreditation standards also expressed the need for change. CDIO aims to develop graduates with the understanding and ability to design, implement, and operate products, processes, and systems [41], [42]. The initiative is a collaboration between MIT, Chalmers, KTH Royal Institute of Technology, and Linköping University.

The early work at MIT caught the attention of Swedish educators and industrialists. In 1999, the CDIO Initiative was established with funding from the Knut and Alice Wallenberg Foundation for four years. They developed pilot programs at each partner university to reform engineering education. CDIO (Conceive - Design - Implement - Operate) focuses on skill development and personal development of informatics engineering students, intending to produce graduates who have both technical knowledge and strategic understanding [42], [43] [44]. CDIO was developed in engineering, while OEP approaches are emerging in various disciplines.

OEP and CDIO have different levels of approach. CDIO emphasizes matching processes to professional practice, while OEP emphasizes matching learning processes to professional practice in a student-centered interpretation. CDIO is more recently established and uses newer approaches, such as outcome-based education [45], [46]. In addition, CDIOs also prioritize the interests of external stakeholders to challenge traditions within the institution [47], [48].

During the development of the CDIO Initiative, the broader program and institution needed to be accommodated. Several distinguishing features of the CDIO program were defined, and the educational reform process became the main focus [49], [50], [51]. The CDIO standards encompass a comprehensive set of 12 that address various aspects of engineering education. These standards pertain to the contextual framework, desired learning outcomes, integration of curriculum, introduction to engineering principles, practical application of design concepts, provision of suitable engineering workspaces, facilitation of integrated learning experiences, promotion of active learning methodologies, enhancement of faculty competencies, implementation of effective learning assessment strategies, and rigors program evaluation processes. A CDIO program assessment rubric complements the standard [49].

CDIO is a holistic and comprehensive initiative to reform engineering education. It aims to produce professionally prepared graduates with technical skills and strategic understanding [52], [53]. CDIO also uses standards and assessment rubrics to measure program quality.

In this research, the authors use qualitative methods to measure the use of SBC devices that are used as learning media containing OER, which have been collaborated with the CDIO education framework to determine the effectiveness and impact given so that it has an impact on the OEP of students of the Faculty of Engineering informatics study program at Madura University.

2. Methodology Section

Figure 1 in the paper illustrates the high-level architecture of the SBCoERs (Single Board Computer Open Educational Resources) ontology. The figure provides an overview of the main components and their relationships within the ontology. The figure shows three main modules: the learning resource module, the user profile module, and the recommendation module. The learning resource module represents educational resources (ERs) and OER and SkilsCommons, and OERCommons. The user profile module captures user-specific information, including learning goals, academic and psychological parameters, and labor market skills. It includes classes such as user, learning goal, and skill.

The recommendation module utilizes the information from the learning resource and user profile modules to generate personalized recommendations. It includes classes such as recommendation, recommendation strategy, and recommendation engine.

The figure also depicts the relationships between the modules, such as the association between learning material and learning goal, indicating that a learning material can be associated with specific learning goals. It also shows the association between user and recommendation, indicating that recommendations are generated for individual users based on their profiles.

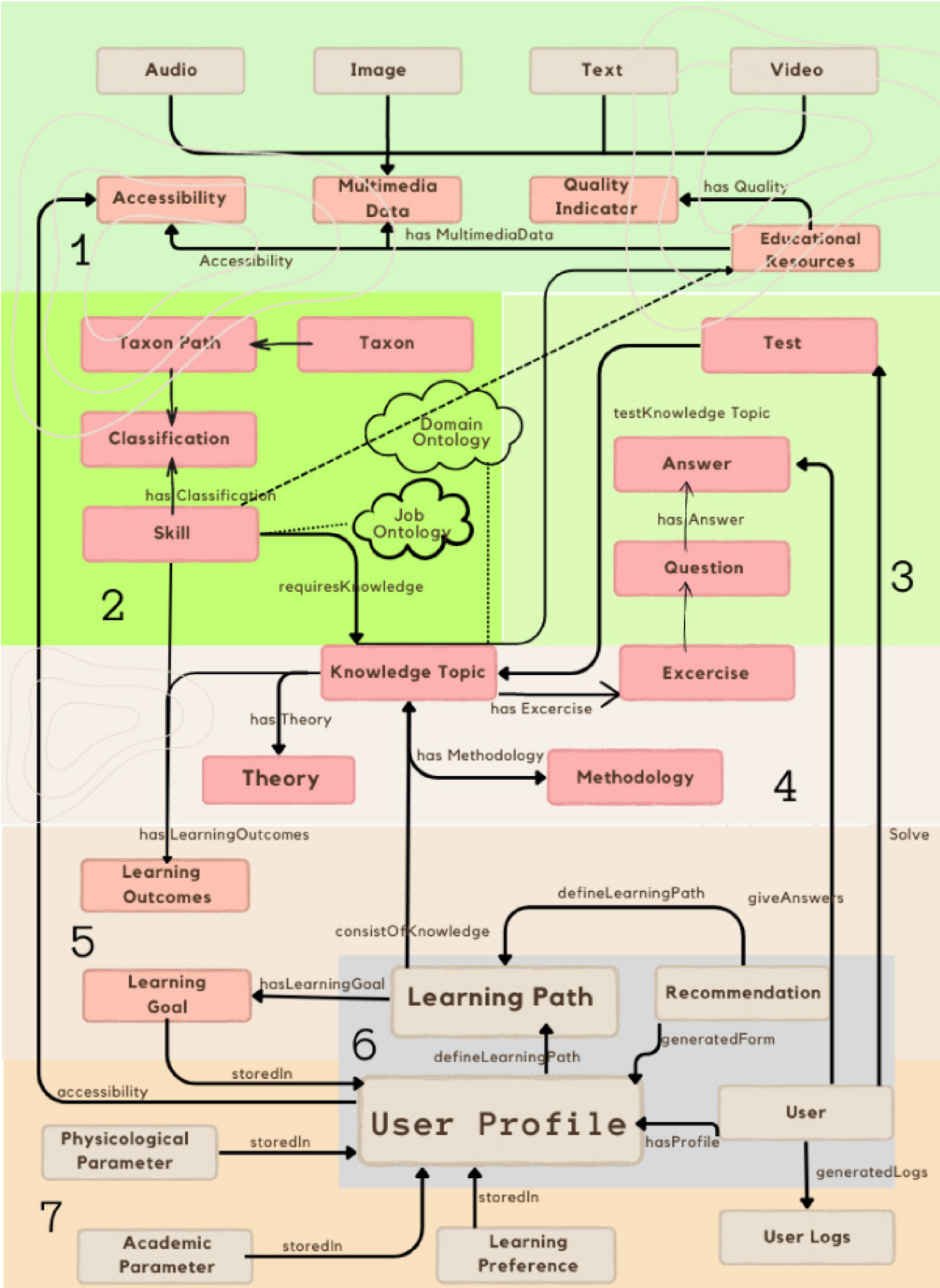

Figure 1. Architecture SBCoERs

The research methodology employed by the CDIO framework involved utilizing qualitative analysis. The study encompassed a sample size of 50 students who actively engaged in the research. The study comprises a control group and an experimental (quasi-experimental) group.

Table 1. Number of participants

Class Type	Number of Student
Control class	25
Experiment class	25
Total	**50**

The experiment was conducted over a 14-week period, during which students participated in SBCoERs activities related to software testing. The SBCoERs experience included an E-Learning, where students progressed by completing exercises and earning rewards. The effectiveness of their test suites and their engagement levels were measured using established metrics.

To ensure the validity of the results, several threats were addressed. These included mitigating the influence of different professors, collecting and monitoring data with the students' informed consent, ensuring the relevance and complexity of the exercises, and using representative programs based on real-life applications.

The conclusions drawn from the study were based on statistical analyses of the data collected. The results indicated that SBCoERs had a positive impact on student engagement and performance in software testing education. However, there was a slight decrease in engagement towards the end of the SBCoERs experience when students realized they would not receive any more rewards. The researchers acknowledged the importance of designing SBCoERs strategies that maintain engagement throughout the experience and planned to readjust the design in future studies.

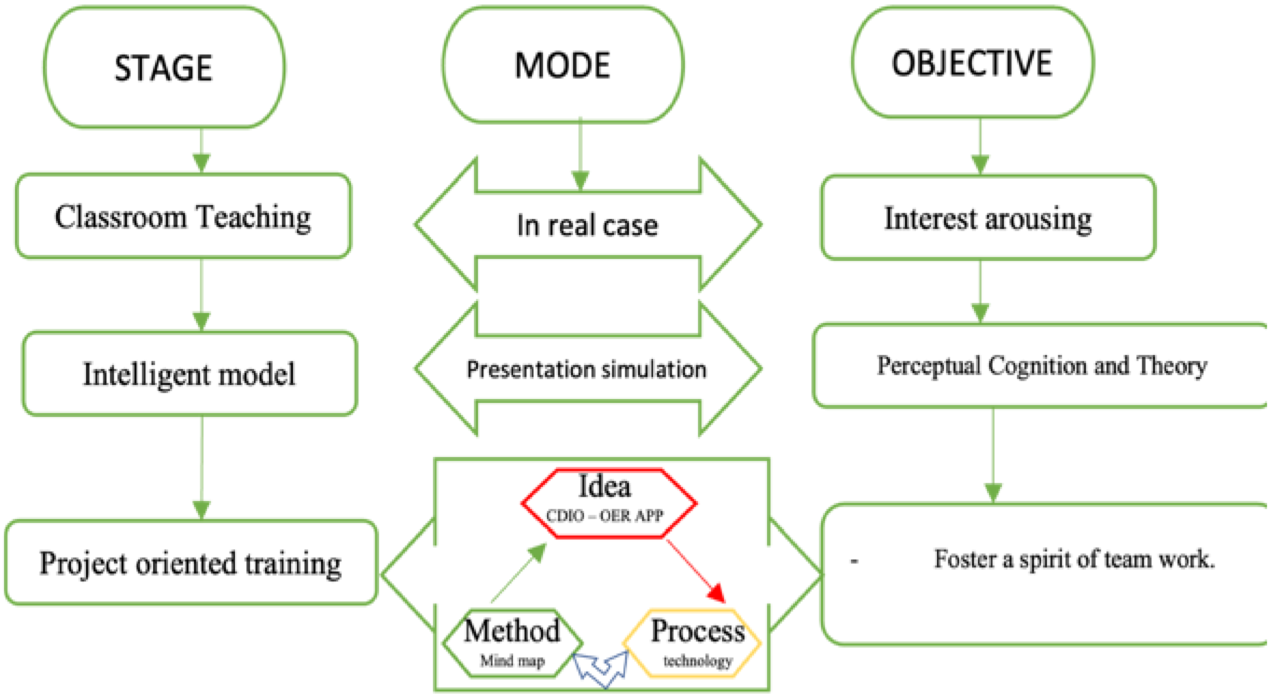

Figure 2. CDIO teaching modes and objective

To evaluate the ontology, the authors used a CDIO based evaluation approach. They selected three well-established repositories for educational resources (ERs) and compared the coverage and adaptability of the SBCoERs ontology to these repositories. The mapping process was conducted by four different developers to ensure objectivity.

The test has been structured to consist of ten essay questions. The ten questions are situated throughout the proficiency levels of C2-C3.

Table 2 displays the indicators of the comprehension of the topics encompassed within learning assessment and evaluation tools. The tool designed afterward undergoes many assessments, specifically validity and reliability testing. The formula for calculating the Content Validity Ratio (CVR) is employed to assess the validity of the measurement instrument. The CVR formula incorporates validation provisions for each item in the instrument. The computation of each item yields a CVR result of 1.00.

Table 2. The identification of indicators that demonstrate comprehension of learning assessment and evaluation materials

No	Kompetensi dasar	Indicators	Cognitive Level	Number of questions
1	Mampu menentukan instrument penilaian yang tepat untuk digunakan dalam menilai pembelajaran siswa	1) Distinguishing instruments that correspond to the realm (cognitive, psychomotor, and affective)	C3	2
		2) Exemplifying instruments that are in accordance with the realm (cognitive, psychomotor, and affective)	C3	2
2	Mampu merancang rencana penilaian melalui pembuatan blueprint instrument penilaian pembelajaran	3) Drafting an assessment plan in the form of a Learning-based Instrument Grid	C4	2
3	Mampu mengembangkan instrument penilaian pembelajaran berdasarkan blueprint yang diberikan	1) Being able to arrange an assessment instrument that is in accordance with the blueprints that have been made	C4	2
		2) Using instruments that have been arranged in the learning process (trial)	C4	2

Consequently, the total CVR for all instrument items on the conceptual understanding ability test is 10.00, establishing its validity. The CVI formula was used to conduct a content validity test on the instrument to assess conceptual understanding ability.

The test yielded a CVI score 1.00, indicating that the instrument possesses excellent validity. The reliability of the capacity to comprehend the notion was assessed using the Alpha-Cronbach formula, yielding a reliability coefficient of 0.850 and indicating good reliability.

Table 3. Indicators of agile learners in the context of learning assessment and evaluation materials

No	Dimension	Indicator	Number of statements
1	Classroom Teaching	1. How well do students know themselves.	2
		2. The extent to which students can treat others constructively and resiliently under the pressures of change	2
		3. The extent to which students know their ability in the learning process	2
2	Intelegent Model	4. Students get the results under difficult conditions.	2
		5. How many students inspire others	2
		6. How many students build the confidence of others with their presence	2
3	Project Oriented Learning	7. Students think about a problem from a new point of view	3
		8. Students are comfortable with the ambiguity of their thoughts to others	3
		9. Students are comfortable with the complexity of their thoughts to others	2
		10. Students feel comfortable explaining their thoughts to others	3
Sum			23

The three dimensions are subdivided into twelve indicators, and each is further divided into twenty-three assertions. Table 3 presents a comprehensive grid illustrating the many devices utilized for agility learning. The coefficient of variation (CV) for each item on the instrument is 1.00, and the cumulative CVR for all items measuring learning agility is 23.00, as determined through the validity assessment of the instrument using CVR. Consequently, the instrument is deemed to possess validity by the validation criteria outlined in the CVR formula. The reliability analysis on the generated questionnaire yielded a Cronbach's alpha coefficient of 0.857, indicating a good level of dependability.

3. Results

The research findings indicate that the utilization of SBCoERs in the context of software testing education positively impacts student involvement and academic performance. The study's findings indicate that students who participated actively in the SBCoERs had superior academic performance to their counterparts in non-SBCoERs settings. Nevertheless, as the program advanced, there was a decline in student engagement, which could be attributed to the absence of supplementary incentives.

The prioritization of OER strategies is of utmost importance in ensuring sustained levels of participation. The researchers intend to enhance the design of the SBCoERs and do a comprehensive longitudinal study to examine the influence of SBC on software testing education. A notable disparity in performance was noted between the control group, comprising those who did not use SBCoERs, and the experimental group, consisting of individuals who used SBCoERs. The experimental group consistently exhibited superior performance compared to the control group. Although the impact sizes are minor.

Overall, the study's findings align with previous research that has reported positive outcomes of SBCoERs' experiences in software testing education. This tool effectively enhances student engagement and performance in this context.

Using single board computers in e-learning, especially with OER and OEP approaches, offers a more inclusive, interactive, and cost-effective way to pay for education. With CDIO's method, learning is more focused on the student, and graduates are ready to face problems in the real world.

4. Discussion

The SBCoER ontology represents a novel and technology-driven methodology for educational purposes. Integrating educational resources, user profiles, and recommendation strategies facilitates the development of a comprehensive educational experience. The learning resources module emphasizes the utilization of OER as a means to democratize technological education. The user profile module facilitates the implementation of customized learning experiences based on the individual requirements of students. The research was carried out utilizing a quasi-experimental methodology spanning 14 weeks, and the findings demonstrated a noteworthy influence of SBCoER. Nevertheless, the findings also indicated a decrease in student involvement throughout the latter stages of the program, underscoring the need to maintain long-term motivation within the educational journey. The use of intrinsic motivators and consistent reinforcement holds significance within instructional strategies.

5. Conclusion

The ontology developed by SBCoER holds significant promise in transforming software testing education. Incorporating resources, user data, and recommendation algorithms inside this ontology showcases a novel methodology in the field of education.

The confirmation of education's future use of technology is evidenced by its impact on student engagement and performance. However, the decrease in student engagement indicates that the human element's involvement remains crucial in utilizing these technologies. The amalgamation of Ooen educational resources (OER) and personalized learning paths, as elucidated by the SBCoER ontology, can potentially enhance student learning outcomes.

Furthermore, it is imperative to prioritize ongoing pedagogical enhancements to tackle the challenges associated with student engagement effectively. This research offers significant contributions regarding technology's effective and enduring integration within educational contexts. The ontology developed by the SBCoERs holds significant importance in pursuing this objective. It is expected to yield favorable consequences for advancing software testing education and its associated domains.

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