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Online STEM education during COVID-19 period: A systematic review of perceptions in higher education

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Abstract

Development of the STEM curriculum played a key role in economic development because it enabled the production of well-qualified production from schools. This development extensively depends on the demonstration of competence in key knowledge areas such as science, technology, engineering, and mathematics disciplines (Dhurumraj et al., 2020). Sustainable STEM education is still in its early stage of development in higher education. Although the COVID-19 pandemic presented unprecedented challenges to this fairly new field, it also helped increase the focus on elements of the Fourth Industrial Revolution, concerning education (Sobrosa Neto et al., 2020). This study systematically reviewed the current articles (n=15) of STEM education in higher education during COVID-19. Results indicated that Faculty members considered the transition from face-to-face to web-based programs effective even though they faced several challenges. Further investigation showed that the application of STEM online learning has helped to increase students' creativity and the rate of STEM research by both students and faculty members. Comparative studies about the differences between the two modes of STEM learning in higher education programs (face-to-face, online) and how they can be harmonized is suggested.

Keywords: STEM in higher education, faculty perception, systematic review, online learning

INTRODUCTION

As the world enter the era of the Fourth Industrial Revolution, there is a need to harness educational systems at the global level in order to prepare future generations and its citizens, so that they can deal with advanced technology. In the future, there would be a need for new skills and jobs, many of which people in general still do not know. The educational systems in the world seek to achieve the sustainable development goals set by the United Nations Educational, Scientific and Cultural Organization (UNESCO), including the fourth goal related to "the quality of education." In order to achieve this goal, a number of changes must be introduced as part of developing the mentality of policy makers and those responsible for implementing the plan Transformation in education. The outbreak of the COVID-19 virus sparked the implementation of various life-changing precautionary measures. In particular, the need for social distance saw a rapid increase in remote learning where learning was reduced to virtual interaction as opposed to the traditional class setting (Cahapay, 2020; Thanawala et al., 2021). From the basic education perspective, thriving private schools made a smooth shift from traditional class-based to online remote learning. On the other hand, under-resourced public learning institutions experienced a not-so-smooth transition. Besides, the sudden transition affected the learners in more ways than physical alone (Sedaghatjou et al., 2021). The global education system has since been in a crisis with the faculty and students alike struggling to cope in the academic environment. Under this circumstance, the digital technology has been integrated with education in a way that never before done leading to generate a new style of education model (Chen & Chen, 2021).

Sustainable science, technology, engineering, and mathematics (STEM) education entails lasting education in various fields. The worldwide recognition of the critical purpose of STEM education has fueled the urgent need to investigate the status and trends in higher education research. In particular, online-based learning

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Contribution to the literature

- This study demonstrates a step by step of PRISMA searching procedures (identification, screening, eligibility and inclusion) to examine the existing literature regarding the experience of STEM education in higher education during COVID-19.
- This study identifies Faculty members' challenges, constraints, and opportunities in conducting online STEM education during COVID-19.
- This study offers the influence of STEM online learning on students' creativity and the rate of STEM research by both students and faculty members.

strategies are receiving increased attention in STEM education (Brancaccio-Taras et al., 2021; EL-Deghaidy et al., 2017). To address the growing need for more STEM-literate instructors, higher education institutions are integrating the STEM curriculum in their teaching processes. Hence the need to investigate different perceptions on the implementation of STEM in higher education during COVID-19. These perceptions can be drawn from faculty and students alike. Educators are the most critical intellectual resources in any field across the world (Vu et al., 2020). For this reason, the present study focuses further on faculty's viewpoints on expanding educational lanes to STEM education through online remote teaching during the coronavirus pandemic.

The investigation is a critical need for efficient teaching and learning in standard higher education. Education must be assessment-centered besides the cumulative skills of learners being established. Under these conditions, then, opportunities for improvement are developed. Unlike the immediate transfer of face-to-face instruction, the online learning curriculum is specially tailored for online instruction, which then requires trained online educators (Black et al., 2021). The pandemic, which is yet to end, requires that regular-school activities be limited to remote operations, a factor that has significantly impacted students psychologically. According to Li et al. (2021), the onset of the pandemic has marketed an increase in mental health cases, including, depression, and anxiety among university students. Academic experts are attempting to establish models of learning approaches that are most effective owing to the current learning settings. According to Sarnita et al. (2021), STEM-based learning can potentially improve learners' creative thinking skills. The model encourages learners to develop, embrace and adopt technology to improve their cognitive skills and scientific attitudes.

In today's world of intense technological revolution, online-based-testing in university-level education has been revealed to be a viable formative assessment exercise at the higher education level (Li et al., 2020). Although virtual-learning interfaces still present challenges in sustained education, they are still required in STEM education. This study presents evidence-based research on online STEM education during pandemic period, particularly among university students.

STEM Education in Higher Education

STEM education does not trace back to more than just a few decades ago. Educational development has for years evolved to reach the current educational system. In the 1990s, the United States National Science Foundation (NSF) created the STEM curriculum which aim to educate students in specific disciplines that included mathematics, chemistry, and physics alongside additional disciplines in social science and psychology, such as linguistics, sociology, and political science (Li et al., 2020). After several years, few stakeholders seemed to know how to operationalize STEM education because it was unclear, where to begin with STEM implementation (Hasanah, 2020). Development of the STEM curriculum played a key role in economic development because it enabled the production of well-qualified production from schools. The sustainable growth of every economy is overwhelmingly reliant on the skills development of the workforce in various economic sectors. This development extensively depends on the demonstration of competence in key knowledge areas such as science, technology, engineering, and mathematics disciplines (Dawson, 2019; Dhurumraj et al., 2020). Chen and Chen (2021) confirmed that students' inventiveness can be predicted using the STEM inquiry technique. It tracks the evolution of creativity as a result of changes in instruction and students' critical-thinking abilities. Creativity is a skill that can be learned, and creative thinking requires a high level of competence. Abdioglu et al. (2021) mentioned that STEM teachers are successful at promoting student creativity through STEM-based educational activities. Furthermore, the STEM inquiry technique might help kids build positive attitudes toward learning. Because of education reform, this is extremely relevant right now. Thus, more effort is needed to realize a major transformative change through the appropriate development of human capital as a key to increasing each country's global competitiveness. In line with these considerations is the need to broaden the educational focus on STEM education within the higher education context. Sustainable STEM education is still in its early stage of development in higher education. Tryfona (2015) suggested that online learning is conducive for teaching STEM graduate courses. Furthermore, Pagoto et al. (2021) explained that advancing higher education is critical to sustainable economic development. Although the COVID-19 pandemic presented unprecedented challenges to this fairly new field, it also helped increase the focus on elements of the Fourth Industrial Revolution, concerning education (Sobrosa Neto et al., 2020). While its applications are still growing, it has played a significant role in improving learning by teaching preservice instructors (Johnstone & Cooper, 2016). Many studies have provided research-backed evidence for sustainable STEM education in virtual learning environments in higher education. For instance, Jeong et al. (2020) examined pre-service faculty's (PST's) performance and motivation in a STEM course in a university setting. The authors observed before and after test results on adaptive class tests. The findings indicate the PST's positive motivation and performance with a positive impact on STEM education.

Research Questions

The following are the research questions addressed by the study:

1. What does the existing research distinguish faculty's perceptions of implementing online STEM education?
2. What do faculty recognize as challenges, constraints, and opportunities to conducting online STEM education?
3. What support do faculty believe would improve their experience in implementing online STEM education?

METHODS

The PRISMA guidelines and flow chart were applied to help outline the items required for transparency in carrying out systematic literature reviews (Zawacki-Richter et al., 2019). The flow chart highlights how the publications were identified, screened, their eligibility, and the inclusion and exclusion criteria for all the publications that were considered for review. The checklist outlines a recommendation list made up of 27 items that include subjects such as title, abstract, background/introduction, research methods, findings, and discussion (Zawacki-Richter et al., 2019). Hence, the PRISMA guideline provides research directions for scholars, reviewers, and editors.

Eligibility Criteria

The review only considered studies that were peer-reviewed and published in scholarly journals not more than five years ago. This means that the journals under consideration had to have been published between 2019 and 2021. On the other hand, newspapers, trade journals, and magazines were not included under this consideration. Additionally, each of the articles needs to address at least one of the research questions in the review (Zawacki-Richter et al., 2019). Only empirical publications were considered, i.e., those that were based on experience and observations rather than pure logic.

Data Sources

The researcher searched electronic databases, specifically ScienceDirect, JSTOR, Web of Science, and Scopus. These databases were selected for their high-quality content and relevance to the topic of study which is concerned with the field of education and social science (Zawacki-Richter et al., 2019). To ensure that all relevant publications had been selected, Google Scholar was utilized due to its limitless provision of search terms.

Literature Search

The researcher commenced the literature search by examining Google Scholar to get a general idea of what has been investigated on the topic of STEM education in higher education during the COVID-19 pandemic. Next, the researcher conducted a systematic keyword search in the earlier selected electronic databases like ScienceDirect, JSTOR, Ebscohost, Scopus, and PubMed. Different keywords were used to assist in finding the most relevant studies to the research topic. The keywords used were "STEM education, online learning, COVID-19, systematic literature review, and perceptions in higher education" combined in various forms to find the most relevant evidence to the study topic. All articles that emerged were then considered. The majority of these studies examined online STEM education in higher education institutions including universities and colleges during the coronavirus pandemic.

Study Selection

Screening

A diagram of the screening process can be seen in **Figure 1**. The researcher applied the following criteria chronologically against abstracts in selecting articles for inclusion:

First criterion: Studies published between 2019 and 2021.

Second criterion: Study is academic/scholarly, i.e., includes original research publications written by scholars and experts in the field of education and social science.

Third criterion: Study is empirical, i.e., includes qualitative, quantitative, or both approaches, or meta-analyses.

Fourth criterion: Obtained evidence is relevant to the present study's research questions and focus.

A total of 15 publications were selected for review through these criteria. The parameters used to search for

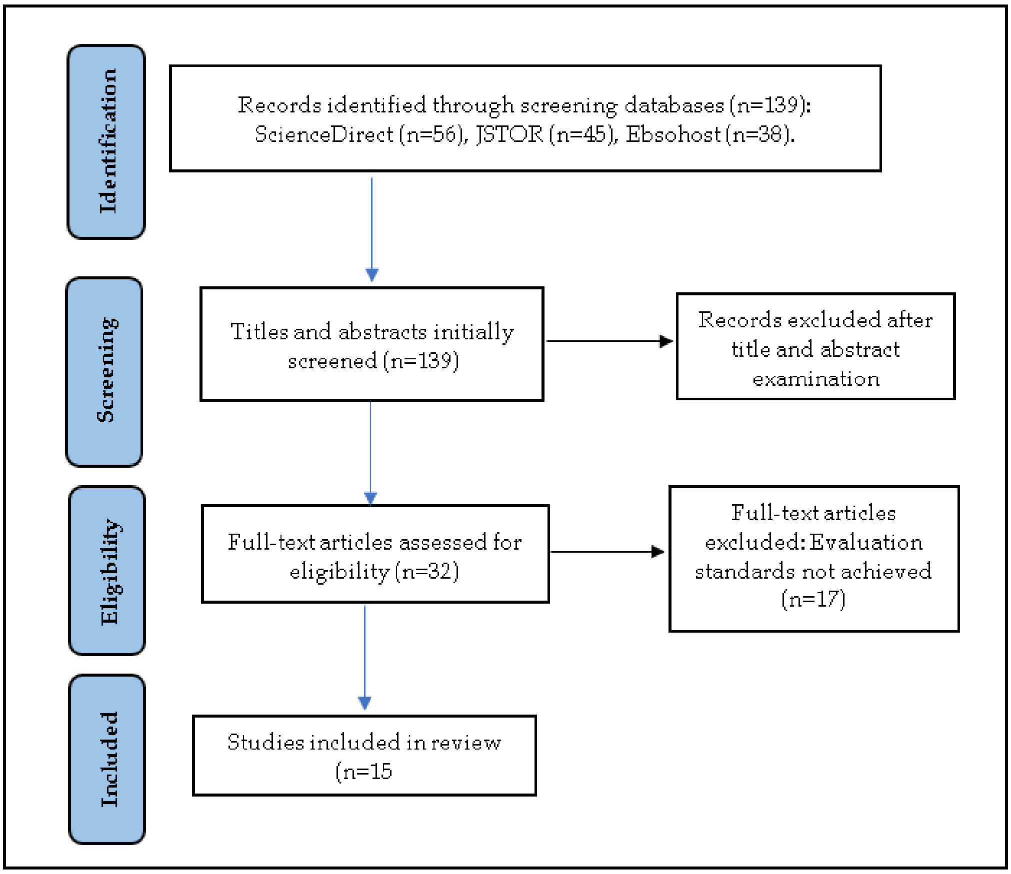

Figure 1. PRISMA flow diagram used in this study

Table 1. Initial search results

Search terms	Database	Limiter	No of articles
STEM and COVID-19	ScienceDirect	Scholarly (peer-reviewed) journals, Published: 2019-2021	56
STEM and online programs	JSTOR	Scholarly (peer-reviewed) journals, Published: 2019-2021	45
Perception of STEM online classes	Ebscohost	Scholarly (peer-reviewed) journals, Published: 2019-2021	38
Total with duplications removed			32

the articles are as illustrated in **Table 1**. After searching for the articles, duplicates and those which do not meet the desired criteria are removed.

Evaluation

To determine the quality of each study, the researcher utilized a special scoring tool that provided the criteria and performance factors that would be assessed in the review (Margot & Kettler, 2019). The rubric evaluated seven criteria which are then used against the full-text contents where each of the seven elements was analyzed to ensure that they adhered to the standards of quality reporting (Mullet et al., 2017). The seven elements were considered against a four-item scale. Part 1-Does not meet standard, Part 2-Almost meets standard, Part 3-Meets standard, and Part 4-Goes beyond standard. Studies were rated for a total possible score of 7 to 28. Studies that achieved a score of 14 or less were excluded from the review for not meeting the quality threshold. Only those that had a score of 15 and above were included for review.

Data Analysis

A systematic review in research welcomes different methodologies that evaluate and analyze prior research to identify existing research patterns and finding. These findings are gauged based on the methods applied to determine which findings are more authentic and applicable in real-world settings (Zawacki-Richter et al., 2019). Since the analysis focus is to identify the relationship in the publications' findings, the research applied the thematic analysis method which involves collecting data from the articles, categorizing them based on their findings, and reporting on the association between the findings. The pre-set coding protocol was categorized, as follows:

a. Online STEM classes/programs,
b. Learners' participation and perception,
c. Professional development, and
d. Lecturers' participation and perception.

The first step of the analysis was to read all 15 articles to identify their main themes, then categorize them

Table 2. Categories and sub-categories

Category	Sub-category
Online STEM classes/programs	Recorded & live virtual classes, research, assessments, technology infrastructure
Learners' participation and perception	Students' challenges, technology expertise, engagement, support, class schedule
Professional development	Virtual internships, practical classes
Faculty participation and perception	Faculty engagement, technology expertise, perception, challenges

Table 3. Quality assessment rubric

Criterion	4–Exceeds standard	3–Meets standard	2–Nearly meets the standard	1–Does not meet the standard
Purpose & objectives	Rational research question and well-articulated objectives	Well-articulated objectives	Poorly articulated	Missing/ incomplete
Literature review	Defines terms, provides research background, & discusses the topic's history	Explains the topic & introduces main ideas	Minimal discussion of the topic with some missing information	Missing/ incomplete
Conceptual frameworks	A detailed explanation of the study theory & framework	The framework is well-aligned with the study purpose	Vague explanation with missing information	Missing/ incomplete
Participants	The sample population is clearly described, sample size & sampling procedure are identified	Adequate description of the research sample population, size, & procedure	Vague description with missing information	Missing/ incomplete
Methods	Measurement instruments are identified, the data collection process is described, data validity & reliability are discussed, & other research best practices are mentioned	Vital information on this section is adequately described & the data sources are identified	Vague description with missing information	Missing/ incomplete
Results & conclusions	Comprehensive results, interpretation of results, & conclusion based on the findings	Vital information on this section is adequately described, the conclusion based on the results, & recommended future research are identified	Vague description with missing information	Missing/ incomplete
Significance	Clearly & convincingly identify the importance of the study	Vital information on this section is adequately described & the data sources are identified	Vague description with missing information	Missing/ incomplete

based on the themes. Sub-categories of the themes such as cultural background, cost of online classes, participation of teacher and learners, learning effectiveness, learning support, technical expertise, and virtual internships were then developed to differentiate the main ideas discussed in the articles. The sub-categories are vital in the research since the conclusive findings constructed based on them. These sub-categories are as shown in **Table 2**.

RESULTS

The analysis of the articles relating to the topic of interest is based on the structure of the research, and how the articles' authors phrased their findings. Thus, analyzing the articles' purpose, objectives, methods used, conceptual frameworks, participants, conclusion and recommendation, and their significance on our research is essential (Zawacki-Richter et al., 2019). The analysis is further based on the four-item scale which included; Part 1-Does not meet standard, Part 2-Almost meets standard, Part 3-Meets standard, and Part 4-Goes beyond standard. **Table 3** shows the quality assessment of the articles depending on the four-item scale.

Perceptions in Higher Education

Perceptions on higher education during the COVID-19 pandemic varied depending on the stakeholders, design of the programs, and other factors. A summary of the retained articles can be found in **Table 4**. The findings of the analysis categorized by our research questions are, as follows.

How does the existing research distinguish faculty's perceptions of implementing online STEM education?

Faculty perception varied from the nature of online STEM programs to their effectiveness, objectivity, performance, and design. Some findings on faculty perception included in the following.

Table 4. Summary of included empirical articles

Author(s) (year)	Participants	Methodology	Findings
Jeong & González-Gómez (2021)	132 pre-service teachers (PSTs), with 68 & 64 PSTs respectively for each group	Effect size (ES) & principal component analysis (PCA) were used to compare different perceptions for both F2F & F2S after completing the course	The analysis showed effective F2F-F2S transition with instructors & PSTs having difficulties in using online lectures
Jeong et al. (2020)	71 students are randomly examined with an online interface for sustainable & flipped formative assessment	Pre- & post-test results on adaptive assignments using a random sample	The flipped online formative assessment interface showed a positive pre-service teachers' (PSTs') performance
Kang et al. (2021)	K-5 teachers	Analysis of teachers' pedagogical practices for STEM using the TPACK framework	The analysis showed that teachers require further professional development especially in technological tools to meet current needs
Li et al. (2020)	Systematic analysis of 798 articles	Systematic analysis	STEM research has increased significantly from 2000 because of the web-based classes
Margot & Kettler (2019)	Systematic analysis of 25 articles	Systematic analysis	STEM instructions should be designed to enhance student-learning outcomes
Miner-Romanoff et al. (2019)	80 STEM courses	Observation protocol Instrument & intra-class correlation (ICC)	The design of online STEM courses should be improved & instructors should be trained
Pagoto et al. (2021)	16 focus groups with STEM undergraduate students from 59 US colleges & universities	Content analyses & descriptive statistics	Universities should develop evidence-based policies that allow the implementation of web-based STEM classes
Sarnita et al. (2021)	5 groups of students taking physics instrument classes	One group pre- & post-test Design with pre-test design Descriptive & qualitative statistical methods are used to analyze the data	STEM-based online learning increases students' creativity
Sedaghatjou et al. (2021)	101 international STEM faculty members	Descriptive statistic	Web-based STEM learning is as effective as face-to-face classes
Stieben et al. (2021)	68 middle school (n=27) & high school (n=41) teachers	Applied t-test and ANOVA to evaluate survey data	Student-centered STEM online teaching & use of technology promote effective learning but some improvements are required
Thanawala et al. (2021)	2,000 STEM students from Bergen Community College (BCC)	Online surveys to test student-student & student-staff interactions	BCC research project showed that web-based learning is essential in STEM course because they improve the interaction between learners & teachers
Wladis et al. (2015)	3,600 STEM students taking online & face-to-face classes	Multilevel logistic regression & propensity score matching	The regression analysis showed that age & ethnicity are factors that contribute to students' success in the online learning experience
Wu et al. (2019)	Students taking online classes-the first cohort took fall semester 2019 (N=25) & the second cohort took fall semester 2020 (N=40)	Use & application of pre-service teachers (PSTs) & technological pedagogical content knowledge (TPACK) in online training & learning environment	Online STEM learning significantly improved the students' TPACK & design thinking
Wu et al. (2021)	24 second-year undergraduates STEM students from a university in eastern China	The teacher's online environment collected data on the participants which was later analyzed using epistemic network analysis (ENA)	Comparison of the study cohorts showed that collaborative STEM learning design has an impact on student's learning & interaction with the teachers
Yusuf et al. (2021)	Students enrolled for a software engineering program in East Java	Surveys were used to collect descriptive data Descriptive statistics were used to analyze data	STEM integrated project-based learning is essential during the COVID-19 pandemic because it allows remote learning for the students

Effectiveness of online STEM programs

Faculty members considered the transition from face-to-face to web-based programs effective even though they faced several challenges (finding 1). During the COVID-19 pandemic, most higher education institutions advocated for online classes to keep the students, faculty members, and other stakeholders safe. Online STEM classes were designed to maximize learning effectiveness for the students while minimizing student-students and student-teacher physical interactions (Jeong & González-Gómez, 2021).

According to Sedaghatjou et al. (2021), the effectiveness of these methods was reliant on students' and teachers' expertise to use the technology tools which could disadvantage some of the students. Other shortcomings included lack of adequate technology infrastructure, poor communication, and uncaring attitude from both students and professors.

Performance

Teachers reported a positive pre-service teachers' (PSTs') performance in the online performance assessments (finding 2). The advantages of web-based learning included flexibility, remote accessibility, and live interaction between teachers and students in some cases (Pagoto et al., 2021). Students' creativity was improved and more performance assessments showed increased input from the students. Some of the factors that affected the student's perception of the online STEM program included the workload, technology expertise, program flexibility, student-teacher engagement, and support from the institution (Chen et al., 2018). The design and implementation process of the STEM program was also an important factor that affected the student's perception and participation.

Online step program design

Some staff members thought that web-based programs design should be improved to increase their effectiveness (finding 3). These STEM online classes' designs and university policies were instrumental to ensure that students continued to learn even when the rest of the world was on lockdown (Pagoto et al., 2021). Pagoto et al. (2021) explain that a variety of online tools such as virtual labs, video calls, and recorded classes supplemented each other to improve effectiveness (Flowers et al., 2012).

What do faculty recognize as challenges, constraints, and opportunities to conducting online STEM education?

Rate of research

The application of STEM online learning has helped to increase the rate of STEM research by both students and faculty members (finding 4). Learning tools like virtual labs and video calls were essential but could not provide authentic learning experiences (Miner-Romanoff et al., 2019). Miner-Romanoff et al. (2019) argue that virtual labs and virtual internships are detrimental to career development because they hinder real-world world experiences (Stieben et al., 2021). Faculties shared the same reservations about using virtual and distant learning technologies.

Expected learning outcome

Online STEM programs designs must consider the students' learning outcomes (finding 5). Li et al. (2020) note that STEM is becoming more important with time. Currently, more students are willing to take classes related to STEM hoping to advance their careers in engineering, mathematics, or technology (Li et al., 2020). STEM programs are designed to help students develop technical skills that will aid them in their careers. However, online classes implemented during the COVID-19 pandemic provided a unique setting that could not allow the development of these skills (Margot & Kettler, 2019).

Training

Some stakeholders think that improvements in online STEM classes are necessary and the instructors should be well-trained (finding 6). Wu et al. (2019) support the idea of training teachers before they start teaching using a web-based approach. Training the lecturers and STEM teachers will provide them with the necessary skills and improve their technology expertise (Wu et al., 2019). Besides, the training will mold their understanding of the teaching approach and allow them to appreciate it more.

Wu et al. (2021) note that the design of the web-based program is instrumental in ensuring that the effectiveness and efficiency of the teaching methods are observed. A self-reporting teacher's study showed that most STEM teachers think that more training is required to improve their expertise in technology and change their perception to be more accommodating (Abdioglu et al., 2021; Kang et al., 2021).

Online STEM education policies

Faculty members believe that universities should develop policies that embrace web-based STEM programs (finding 7). Although universities were not entirely ready to implement the web-based STEM classes, they acted swiftly to develop the required materials, technologies, and policies to support the student in their learning needs. Universities also developed policies that enabled students to learn remotely without reporting to the universities.

What support do faculty believe would improve their experience in implementing inline STEM education?

Students' creativity

Some education stakeholders think that STEM-based online learning increases students' creativity (finding 8). Li et al.'s (2020) idea is supported by Sarnita et al. (2021) who explains that STEM subject promotes creativity in students. Thus, more students have a positive perception of STEM subjects because the subject increases creativity and innovation. Furthermore, research showed that web-based learning attracted more students than traditional learning methods (Sarnita et al., 2021).

DISCUSSION

Although all the articles evaluated web-based STEM programs and the impact they had on the learners, the faculty perception greatly varied with some focusing on the effectiveness of the programs while other view point was on learners' involvement (Wu et al., 2021). The articles finding supports implementation of online STEM education citing effectiveness, improved creativity in learners, and flexibility. The learning programs are advantageous to the learners and the faculty and necessary during the COVID-19 pandemic because they minimize the of spread of the disease in universities (Yusuf et al., 2021). However, faculty members expressed their discontent with the online STEM programs by highlighting a number of shortcomings they experienced. This finding is consistent with the results of the Tertiary Education Quality and Standards Agency of the Australian Government (2020) report that investigated students experience of education transition to online learning and one of the most critical issue students faced was staff expertise with using the IT applications which led to 50% of students were unsatisfied with their online experience and reported not to enroll in this type of courses again. Therefore, preparing faculty members in utilizing technology effectively in a way that encourages students to be engaged and interacted. According to Kang et al. (2021) additional professional development and training is essential for the faculty. Therefore, developing training plans in light of the requirements of integration of STEM in each scientific discipline of the scientific colleges; and developing the competencies of university faculty members in light of their actual needs, especially with regard to comprehensive quality standards are essential to keep up rapid developments in the field of professional development.

Additionally, some researchers found that universities need to allocate more resources to development of infrastructure and other tools required in web-based learning. Institutions also need to develop more policies to guide on faculty on web-based learning and incentivize the programs to attract more students. The relevant higher education programs might be reconsidered in terms of ensuring its suitability to online learning delivery mode and in a way that enhances students' life skills through sustainable development. United Nations Educational, Scientific, and Cultural Organization (2020) responded to the education transition challenges during COVID-19 and emphasized that planning for distance education and its improvement in all aspects makes it more in line with the needs of learners, and raises learning outcomes, so it is necessary to provide elements for education quality. One of the most important elements is the digital content industry, where digital content quality assurance for distance education poses a great challenge for instructors (time, effort, sufficient knowledge of content creation); therefore, some instructors turn towards web-based scientific materials such as YouTube, digital libraries, and lessons available via platforms. However, in most cases, the objectives of the courses do not meet, and sometimes they may not be compatible with them. Therefore, it is essential to produce special content. This requires knowledge of the educational material, pedagogical knowledge of teaching strategies and its delivery to learners of different types. Among the most prominent forms of digital content sources are internal sources, where a specialized team within the educational institution develops distance education courses. The second form of digital content sources is external sources, which are represented in educational institutions contracting with educational organizations, specialized experts and publishers to produce and develop distance education courses. Micro-learning is another form of digital content and is represented in the internal development of courses by enhancing it with educational videos, simulation systems and virtual laboratories that serve to achieve the desired objectives.

CONCLUSION

STEM education not only involves teaching these disciplines and topics in isolation, but also involves taking an interdisciplinary approach. It also recognizes the strong connection between STEM education and the arts that foster design, creativity, and innovation. This requires providing and creating a virtual learning environment in a way that helps learners to enjoy and engage in workshops that integrate these sciences, and enables them to develop their knowledge and skills in a way that allows them to understand and understand science in an easy and easy way and in an enjoyable learning style, so that the impact of these skills extends to include all the learner's educational activities in life and commensurate with the natural and geographical variables. This type of environment requires management with a high degree of efficiency and professionalism in dealing with it effectively and achieving the desired objectives. STEM education as a cutting-edge technology has piqued the interest of researchers and educators alike. In order to put ideas into action for a comprehensive and multilateral update of the content and essence of preparing schoolchildren for creative work and successful lives in the digital space in the near future, it is necessary to develop and implement measures to revise the entire content of future pedagogical training today (Mikhaylovsky et al., 2021).

Further studies in this area should be conducted to find out how different web-based programs are different from face-to-face programs, and how they should be harmonized. Besides, program's effectiveness should be evaluated using well-designed studies. Student's perception on web-based STEM learning should also be assessed. Research into overall outcome of online STEM programs is necessary. The systematic review of the 15 journal articles helped to evaluate perceptions in Higher education during the COVID-19 pandemic by students, teachers, and faculty. Furthermore, the effectiveness of web-based learning should be reviewed to determine its effectiveness over other modes of learning. Finally, a review of university policies that encourage web-based learning is vital.

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