

Integration of computer-based technology in smart environment in an EFL structures

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Abstract. One of the latest teaching strategies is smart classroom teaching. Teaching is carried out with the assistance of smart teaching technologies to improve teacher-student contact, increase students' learning autonomy, and give fresh ideas for the fulfillment of students' deep learning. Computer-based technology has improved students' language learning and significantly motivating them to continue learning while also stimulating their creativity and enthusiasm. However, the difficulties and barriers that many EFL instructors are faced on seeking to integrate information and communication technology (ICT) into their instruction have raised discussions and concerns regarding ICT's real worth in the language classroom. This is a case study that includes observations in the classroom, field notes, interviews, and written materials. In EFL classrooms, both computer-based and non-computer-based activities were recorded and analyzed. The main instrument in this study was a survey questionnaire comprising 43 items, which was used to examine the efficiency of ICT integration in teaching and learning in public schools in Kuala Lumpur. A total of 101 questionnaires were delivered, while each responder being requested to read the statements provided. The total number of respondents for this study was 101 teachers from Kuala Lumpur's public secondary schools. The questionnaire was randomly distributed to respondents with a teaching background. This study indicated the accuracy of utilizing Teaching-Learning-Based Optimization (TLBO) in analyzing the survey results and potential for students to learn English as a foreign language using computers. Also, the usage of foreign language may be improved if real computer-based activities are introduced into the lesson.

Keywords: computer-based technology; EFL Structures; ICT; smart environment; TLBO method

1. Introduction

In the 21 century, the phrase "technology" is an essential topic in many disciplines as education. This is because technology has replaced paper as the principal medium of information delivery in many countries. Nowadays, technology integration has been conducted by advancements and changed our society, which has completely affected our thinking, working, and living (Grabe and Grabe 2008, Moghadam *et al.* 2010, Zhou *et al.* 2022). Accordingly, schools and other educational centers that are designed to bring the learners to live in a "knowledge society" must regard the combination of ICT into their curricula (Arnseth and Hatlevik 2010, Ghavifekr *et al.* 2012, Kazerani *et al.* 2017, Ghanbari-Ghazijahani *et al.* 2020). While the aim of ICT is to enhance and raise the quality, accessibility, and low cost instruction convey to students, it also refers to the benefits of networking learning communities to provide the problems of present globalization (Cao *et al.* 2021a, Albirini 2006, Jahandari *et al.* 2021a, Li *et al.* 2021, Qi *et al.* 2021). ICT application is not a one-time event, but rather a set of ongoing and ongoing procedures that fully improve

teaching - learning beside the information resources (Young 2003, Jahandari *et al.* 2021b, Miraki *et al.* 2021, Sadeghian *et al.* 2021a). ICT combination in education normally refers to a technology-based instruction and learning procedure that is closely linked to the usage of learning apparatus in schools (Li *et al.* 2019, Yan *et al.* 2021). ICT combination in schools, especially in a class is crucial since children are comfortable with technology and learn better in a technology-based setting. This is due to the fact that the use of technology adds significantly to the teaching aspects where ICT could result in a successful learning with the aid and support of ICT elements and components (Jamieson-Proctor *et al.* 2012, Majedi *et al.* 2020, Afrazi and Yazdani 2021, Mehdizadeh *et al.* 2021, Sadeghian *et al.* 2021b). Thus, ICT assist the teachers and learners while a successful learning occurs using computers as learning aids (Jorge *et al.* 2003). This is not the case to replace the computer and technology to good teachers, rather it is considered as an aid to improve teaching - learning (Cao *et al.* 2020, Aldrees *et al.* 2021). Whilst ICT is not a one-time learning process, rather it is a continuous learning process that provides a proactive teaching-learning environment (Young 2003). ICT may be used in different models to assist both instructors and learners in learning about their respective topic areas. This technology offers various exciting techniques as stimulation, instructional movies, data

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storage, mind-mapping, brainstorming, music, database use, and guided discovery to provide the learning experience more meaningful (Finger and Trinidad 2002, Nowroozi *et al.* 2021, Rouhanifar *et al.* 2021). Learners take the advantageous of ICT since they won't be constrained by a restricted resources and curriculum; however, hands-on activities in a technology-based course are prepared to assist learners improve their comprehension of the subject (Soman *et al.* 2014, Nam *et al.* 2015, Li *et al.* 2019). It also assists instructors in designing their lesson plan in an innovative and proper manner, resulting in the learners' active learning. Previous research has demonstrated that incorporating ICT in the classroom enhances the learning procedures and raise the learners' active learning skills (Finger and Trinidad 2002, Jorge *et al.* 2003, Young 2003, Jamieson-Proctor *et al.* 2012). Some researchers highlighted three major stages in which ICT might be highly appreciated and respected by teachers: integration, enhancement, and complimentary. The integrating of technique encompasses implementing suitable ICT use in a given subject area with difficult notions and abilities to promote the learners' performance and attainment. Further, a curriculum review is necessary to ensure that only related ICT materials and relevant software are installed to achieve the curriculum's key goals and objectives. The technique for improvement comprises employing ICT to place a significant emphasis on the issue provided. Microsoft Power Point e.g., might be applied to offer the topic in a highly innovative and creative manner, resulting in discussion and the exchange of ideas and perspectives (Wang *et al.* 2009, Ye and Ni 2012, Taj *et al.* 2020). Finally, a complementary method is one that uses ICT to improve and encourage student learning. This strategy enables students to be more disciplined and successful by taking notes on the computer, submitting assignments through email till deadline, and look for material from various internet sources to finish the assignment allocated to them (Hermans *et al.* 2008). Technology-enhanced teaching and learning may result in multiple classroom benefits, but proper planning and policy formulation are essential. According to recent research, national ICT policy may perform a number of key functions. They provide a rationale, a set of objectives, and a perspective of how education could function if ICT was integrated into the teaching - learning procedure, and they help learners, teachers, parents, and the general population of a certain nation (Chan 2002). Infrastructure and ICT facilities, on the other hand, are necessary to supply schools across the country. The availability of computer laboratories and ICT facilities is a critical component in the use of ICT. This is done to ensure that topic instructors have ready access to ICT tools anytime needed. One of the main challenges that schools face, especially in rural areas, is the lack of appropriate Technology and internet access. Instructors cannot use the computer if there is a lack of technical support and no repair is available (Jamieson-Proctor *et al.* 2012). Due to the obvious risk of equipment failure, instructors would be discouraged from using computers if they did not receive any training on the issue. According to this research, technical concerns are a significant barrier for

instructors. These problems include a lack of connectivity, a virus assault, and a faulty printer. Nonetheless, there are a few examples, such as the Netherlands, the United Kingdom, and Malta, who recognized the need for technology to aid instructors in using ICT in the classroom (Yang and Wang 2012). Furthermore, the desire and ability of instructors to use ICT play an essential role in the use of ICT in education. Instructors must have strong ICT skills and a high level of confidence to utilize the method in the classroom. In addition, in order to properly employ ICT in the classroom, educators should first comprehend its pedagogical objective. Instructors who have finished an ICT course are more successful than those who have not received such courses in using technical methods in their class. A similar example occurred in Canada, where several teachers acknowledged to being reluctant ICT users because they were afraid of being embarrassed since their students understood more about the technology than they did. Schools have used a range of techniques to provide extra training for instructors beside their basic skill training (Meng *et al.* 2021). Teachers need to know the relevance and advantageous of ICT, based on Warwick and Kershner (2008), to conduct a good class with ICT. As prior mentioned, there are various factors that allow ICT to be used in a class. Likewise, frequent technical help and continuous professional growth in ICT should be offered. To summarize, all parties must collaborate to advance the nation's technical condition.

Undoubtedly, ICTs have altered our perceptions of time and place, opening us new ways for accessing information and influencing knowledge generation (Collis 1996). The usage of mobile devices has raised the notion that the location and context of learning are unimportant. However, places (both physical and virtual) are not meaningless; in contrast, they are becoming increasingly significant and learning environment design must coordinate many locations in which a person might learn and integrate formal and informal scenarios. It is also worth noting that location is a key part of adaptability and personalization in mobile devices. The usage of mobile devices allows users to construct and manage additional features of real-world location-based scenarios or contexts (Cook *et al.* 2011). Burbules (2012) observes that for learning to be really ubiquitous, it must be disseminated over time and place. It is commonly established that a ubiquitous learning environment is one in which the learner may be learning without even realizing it (Xie *et al.* 2020). Along these lines, the boundaries between "work/play, learning/entertainment, accessing/creating information, public/private, formal/informal are distinctions that have previously been theoretically apparent but are now becoming ambiguous" (Burbules 2018), p. 2]. When (Chatti *et al.* 2010) said that learning is inherently personal, social, dispersed, ubiquitous, adaptable, dynamic, and complex in character, they summed up the future difficulties in education quite effectively. "A fundamental change is required toward a more customized, social, open, dynamic, emergent, and knowledge-pull model for learning, as opposed to conventional learning solutions' one-size-fits-all, centralized, static, top-down, and knowledge-push



Fig. 2 Smart education in science

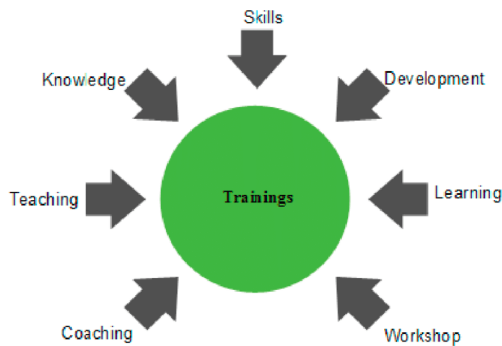


Fig. 3 Diagram of training including the sub skills

and how it helps the creation of customized and adaptable learning. Furthermore, IoT and portable technologies can aid in the development of contextual learning (Zhu *et al.* 2016). Smart technology and software may be utilized to assist and develop learning. These objectives are served by hardware, such as an interactive blackboard, smart table, e-bag, mobile phones, and portable gadgets as well as software, such as computer teaching games, virtual reality, and learning analysis (Luo *et al.* 2021e). In addition to traditional educational activities, information and communication technologies enable many virtual programs and assist groups with special needs in learning and developing abilities. Fig. 2 shows the Smart Education as a science education program in which students can learn scientific principles quickly and easily through cutting-edge IT technology-based two-way experiences.

1.2 The structure of smart learning

There is no uniform definition of smart learning in the literature; nonetheless, it can be concluded that it includes three essential components: smart environment, smart learning methodologies, and smart learners. Smart learning practices have a significant impact on smart environments, both of which contribute to the development of smart learners. Fig. 3 indicates the diagram of training including the sub skills.

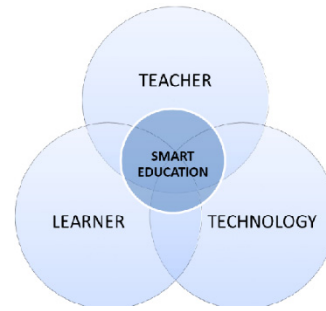


Fig. 4 The triangular smart learning

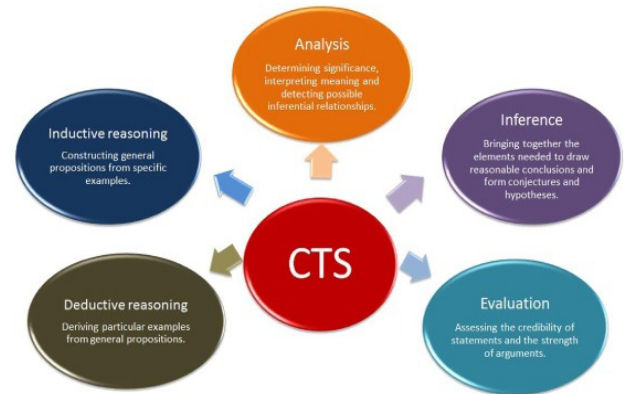


Fig. 5 Critical thinking sub categories

1.3 Smart learners

The process of obtaining and digesting knowledge is referred to as learning. The twenty-first century requires skills and professional knowledge in order for individuals to use their job and leisure time efficiently, and preparing for this is the responsibility of education. There are four levels of abilities that students should acquire in order to meet the demands of modern society, according to smart education. These abilities include fundamental and main capabilities, comprehensive attributes, personalized abilities, and collective intelligence. Fundamental and primary skills related to information and abilities are obtained through so-called basic topics, such as writing, reading, art, STEM and so on, which are required for success. Critical thinking and the capacity to handle real-world problems are examples of complete abilities that prepare students to argue and think critically in difficult settings (Fig. 5). Individualized talents need extensive information and technology expertise as well as the acquisition of creativity and inventive skills. Information and technology knowledge need the acquisition of ICT-skills from students (Fig. 3), including the usage of various ICT programs and the capacity to combine them with cognitive or higher level of thinking. Creativity and innovation need creative thought and collaboration with others (Guo *et al.* 2021). Collective intelligence is a knowledge generated by the communication and cooperation of a group of individuals (Fig. 4). Students must be able to communicate efficiently, and effective communication necessitates that they work effectively and respectfully in various work groups (Zhou *et al.* 2021).

1.4 Smart learning techniques

The following teaching strategies can be highlighted to increase learners' performance: individual studying, differentiated teaching in the classroom, cooperative group work, and generative mass based learning (Mária 2010, Spector 2014). Differentiated educations are a procedure in which learners with varying abilities study together, but teaching and learning are tailored (Mária 2010). In group learning based on collaboration, learners study in groups, organize and divide tasks collaboratively, and each student is accountable for the task's accomplishment. The teacher's role is just to supervise and assist as required (Kong *et al.* 2021, Ágnes 2004). Because of the advancement of computers and ICT, a new paradigm of education technology has emerged as computer-assisted cooperative learning (CSCL) (Koschmann 1996) CSCL focuses on the role of ICT in cooperative learning. Individualized learning necessitates a student-specific learning approach and assignments. In contrast to external motivation, pupils' particular interests are more essential since they are motivated by their enthusiasm. During this procedure, students succeed via their own inner motivation, then find their interest. Students who study online may link old and new material, gain basic knowledge, and apply metacognitive abilities. Online learning also leads in the elimination of time and space limitations.

1.5 Smart learning environments

Traditional learning strategies have been criticized for being excessively unnatural, inflexible, and unresponsive to current social conditions. Using ICT has become a common occurrence in the digital era. Children nowadays may be referred to as digital indigenous, as they are able to utilize mobile devices and digital sources on a daily basis, so the learning environment was altered. There is no generally agreed concept of a smart learning environment (SLE). The key aspect of the smart learning environment, according to Jonathan Michael Spector, is the employment of innovative techniques that give students more adaptability, flexibility, feedback, efficiency, and incentive (Zhao *et al.* 2021b, Natividad *et al.* 2015). According to Zhi-Thing Zhu, Ming Hua Yu, and Peter Riezebos, the goal of smart education is to provide lifelong learning that aim at improving learners' intelligence and problem-solving skills through contextual, individualized, and adaptive learning (Zhu *et al.* 2016). According to Ronghuai Huang, Junfeng Yang, and Lanquin Zheng, smart environment is a type of space for learning or activities that realizes learning scenarios, defines the learners' personalities, provides appropriate learning sources and interactive devices, and automatically records and assess the learning process. The SLE is a high-level digital learning environment that has been resulted from the advancement of educational technology (Liu *et al.* 2021b).

1.6 Objective of study

The initial objective of this research is to assess the efficiency of ICT integration. This research seeks to investigate (I) the efficiency of ICT from teaching - learning

perspectives, and (II) the successful features of ICT integration in teaching in Kuala Lumpur public schools. In order to make digital remodeling available, the user-friendly look of current tool systems and IT education apps is unavoidable. However, it appears that incorporating ICT technologies into educational practice is not as straightforward as we may think. Several issues can limit integration into the educational process, and discouraging many people from considering ICT. New expectations need the acquisition of new abilities, which results in the restructuring of the educator's position. According to our observations, some instructors in this profession still believe in conventional means to assist education, making the incorporation of ICT tools into the educational process more challenging. The paper investigates the reasons for utilizing the potential provided by smart instruments in education to a greater extent, hence to increase its efficiency (Zhao *et al.* 2021f). TLBO (Zhao *et al.* 2020a) would also assess the findings of questionnaires and surveys administered to instructors and students in order to appropriately depict the impact of computer-based technology in smart learning.

2. Methodology

2.1 Research design

In this study, quantitative approach was employed to gather and evaluate data from all respondents. The questionnaire was made and completed by the researchers prior being distributed to the intended group of respondents. A few sections of the questionnaire were especially constructed to meet study goals pertaining to the efficacy of ICT for learners in learning and effective features of ICT integration in public schools in Kuala Lumpur. As a result, the questionnaire was set in order to collect data from the respondents.

2.1.1 Population and Sampling

The total number of participants for this study was 90 instructors from Kuala Lumpur's public elementary schools. The questionnaire was sent at random to respondents with a teaching background, despite the ethnicity, experience or gender. Since the intended respondents for this research have teaching experience, the researchers attempted to recruit instructors from public primary schools in Kuala Lumpur in particular.

2.2 Instrument

The main instrument in this study was a survey questionnaire comprising 43 items which was used to examine the efficiency of ICT integration in teaching and learning in public schools in Kuala Lumpur. A total of 90 questionnaires were provided, with all respondents being asked to read the statements and select their replies using a 4-Likert scale ranging from 4 = Strongly Disagree, 3 = Disagree, 2 = Agree, and 1 = Strongly Agree. The questions were divided into four pieces. Section A is about the respondents' demographic background and comprises 8

Table 1 Mann-Whitney U-test between teacher’s perception of ICT integration and school’s type

Type of school	N	Median	Range	Mean rank	Mann-Whitney U	p
Score B Primary	40	2.36	2.20-2.43	49.87	655.00	0.02**
Secondary	50	2.10	1.95-2.44	35.85		

Table 2 Mann-Whitney U-test between the effectiveness of ICT integration for students in learning with school area

School area	N	Median	Range	Mean rank	Mann-Whitney U	p
Urban	80	1.65	1.31-2.00	54.92	237.00	0.01**
Rural	40	1.56	1.43-2.35	56.64		

elements, such as gender, race, teaching experience, kind of school, school location, preferred teaching style, highest academic qualification, and capacity to handle ICT in teaching (Fig. 6). The questionnaire’s other three sections are mainly concerned with teachers’ perceptions and the aspects of efficacy of ICT usage in schools (Table 1). Part B includes 15 items that examine their view of ICT in instruction, part C includes 10 items that examine the efficacy of ICT integration for students in learning (Table 2), and part D includes 10 items that examine the effectual features of ICT integration in teaching. The questionnaire utilized for this quantitative investigation was adapted and change following the Gulbahar and Guven (2008) model deemed appropriate for this study (Fang *et al.* 2021).

2.3 Teaching–Learning based Optimization (TLBO)

TLBO is an interaction between the teacher and learner in a teacher-learner or among learners in a class to test all the feasible solutions for an optimization problem as Learners. The knowledge obtained by a learner in a given subject is the value of design variables. TLBO is going to strength this knowledge to advance the value of design variables, which led to the optimum solution (Wu *et al.* 2021a). TLBO works in two phases as follows (Cao *et al.* 2021a):

- (1) Initializing learners in which N number learner learn D number subjects, and learners show the possible resolutions, whilst the subjects are the decision values that need to be optimized in problem (Wu *et al.* 2021b). Students are initialized by the values between 0 and 1 for each learned subject. i_i learner is shown by the row vector x_i .

$$\begin{aligned}
 X_i &= [x_{i,1}, x_{i,2}, x_{i,3}, \dots] \\
 i &= 1, 2, 3, \dots, N \\
 j &= 1, 2, 3, \dots, D
 \end{aligned}
 \tag{1}$$

- (2) Teacher Phase in which the fitness for each learner x is computed through fitness function fx . Learner with an optimal fitness variable is taken as Teacher (X_{teach}). Later, the mean knowledge of a student is computed for each subject as Eq. (2)

$$\begin{aligned}
 X_{mean} &= [\bar{x}_1, \bar{x}_2, \bar{x}_3, \dots, \bar{x}_j] \\
 \text{where } \bar{x}_j &= \left[\frac{\sum_{i=1}^N x_{i,j}}{N} \right]
 \end{aligned}
 \tag{2}$$

$X_{teacher}$ shows the teacher that improves the knowledge of all learners (X_i) by

$$\begin{aligned}
 X_{new} &= X_i + (rand() \\
 & * (X_{teacher} - (TF * X_{mean}))) \\
 i &= 1, 2, 3, \dots, N
 \end{aligned}
 \tag{3}$$

$TF = round(1 + rand())$ influencing the of X_{mean} value
 $rand() = \text{random value between } 0 \text{ and } 1$

It is not considered as a TLBO parameter because the

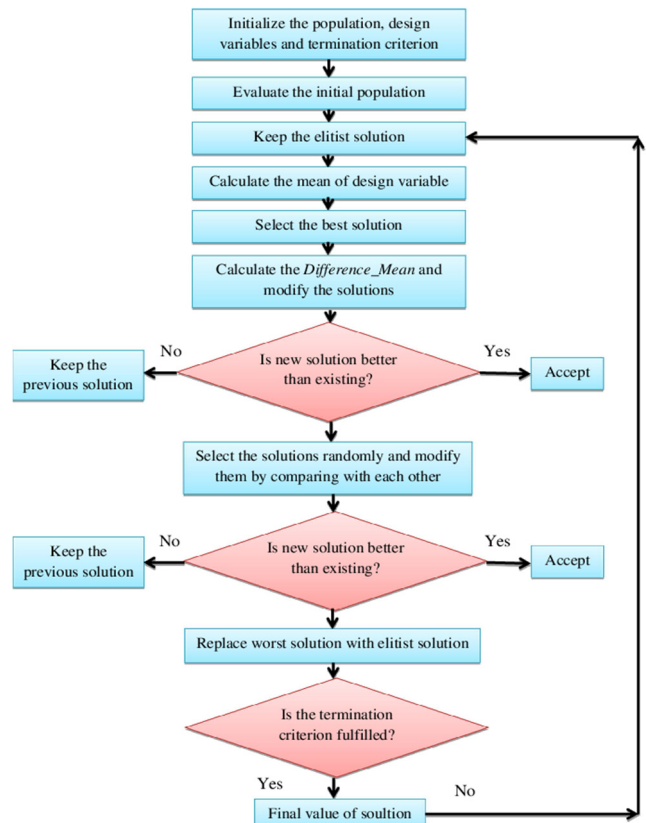


Fig. 6 TLBO diagram

value is calculated arbitrarily using the Eq. (9). If the fitness of revised solution x_{new} is better than the prior solution X_i , then it is updated as the new learner variable or is rejected. 3) Learner Phase in which there is an interaction among learners to enhance their knowledge (Chen *et al.* 2021). Based on this algorithm, learner A learns from learner B, if learner B is more knowledgeable. Thus, if the fitness of B is better than the fitness of A, knowledge is transferred. Two students X_i and X_j are randomly chosen as $i \neq j$. If the fitness of X_i ($f X_i$) is better than, then X_i is updated to X_{new} as follows

$$X_{new} = X_i + rand() * X_i - X_j \tag{4}$$

Therefore, it is updated as

$$X_{new} = X_i + rand() * X_j - X_i \tag{5}$$

If the fitness of X_{new} is better than X_i , then $X_i = X_{new}$ else X_{new} is rejected.

Step 2 and 3 are iterated up to the end of criteria, if the highest number of generations is gained or the average fitness variable for all students is not improved. Regarding that X_i has the best fitness value, $f X_i$ is deemed as the final resolution to the optimized problem (Fig. 6).

3. Result and discussion

3.1 Model performance indicators

According to the available data derived for comparing the results of the model (TLBO), statistical model performance indicators of determination coefficient (R^2), root mean square (RMSE), and Pearson correlation coefficient (r) were used in MATLAB.

$$R^2 = \frac{[\sum_{i=1}^N (O_i - \bar{O}) \cdot (P_i - \bar{P})]^2}{\sum_{i=1}^N (O_i - \bar{O}) \cdot \sum_{i=1}^N (P_i - \bar{P})} \tag{6}$$

$$r = \frac{N(\sum_{i=1}^N O_i \cdot P_i) - (\sum_{i=1}^N O_i) \cdot (\sum_{i=1}^N P_i)}{\sqrt{(N \sum_{i=1}^N O_i^2 - (\sum_{i=1}^N O_i)^2) \cdot (N \sum_{i=1}^N P_i^2 - (\sum_{i=1}^N P_i)^2)}} \tag{7}$$

$$RMSE = \sqrt{\sum_{i=1}^N \frac{1}{N} (O_i - P_i)^2} \tag{8}$$

P = predicted values

\bar{P} = predicted values

O = observed values

O_i = observed values in sample i

\bar{O} = mean of observed variables

N = number of training or testing samples

P_i = predicted values in sample i

3.2 Result and discussion

The initial objective of this research is to assess the efficiency of ICT integration in smart learning - teaching. This research seeks to investigate (I) the efficiency of ICT from teaching - learning perspectives, and (II) the successful features of ICT integration in teaching. The paper investigates the reasons for utilizing the potential provided by smart instruments in education to a greater extent, hence to increase its efficiency. TLBO was used to assess the findings of questionnaire and survey administered to instructors and students in order to appropriately depict the impact of computer-based technology in smart learning. In this case, Fig. 7 shows demographic background results of teachers in responding the questionnaire. In this figure the three parameters of race, gender and teaching experience have been taken, in which teaching experience has been shown as a major parameter in teachers' responses than gender and race. It means that the teachers' experience played greater role in their view toward using ICT than their gender and race. Fig. 8 shows the view of participants in the integration of ICT in Teaching –Learning process. There is a raising in the mean value of respondents, showing the agreement of the participants in using ICT in smart learning- teaching. Figs. 9 and 10 show the efficiency of ICT in Learning and teaching. In both figures, there is an obvious increment in the mean value of the respondents. It shows the satisfactory effect of ICT in smart learning and teaching. Going through the diagrams of TLBO in

analyzing the results gained from the survey and questionnaire, Figs. 11-16 have been built. At first, all data were normalized to reduce their noise (Fig. 15). Meanwhile, Fig. 11 depicts the distribution of predicted and observed

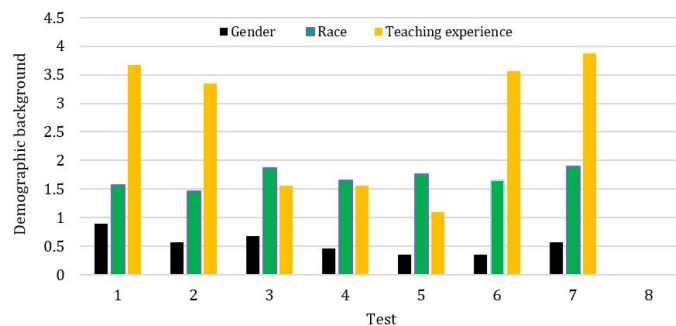


Fig. 7 Demographic background results of teachers in responding the questionnaire

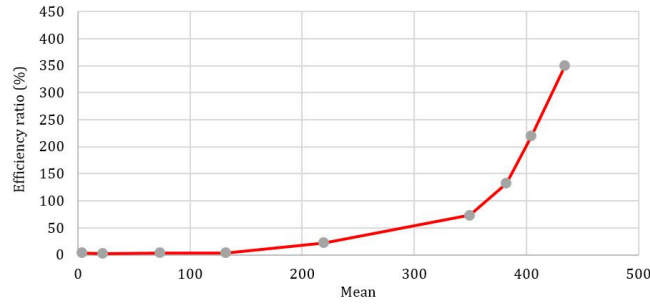


Fig. 8 The view of participants on ICT integration within the smart Teaching –Learning process

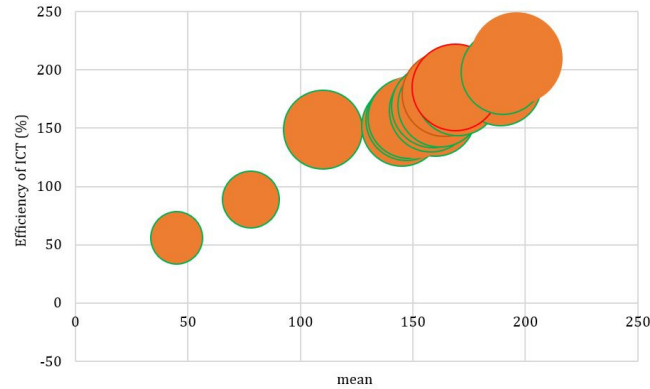


Fig. 9 Efficiency of ICT in Learning

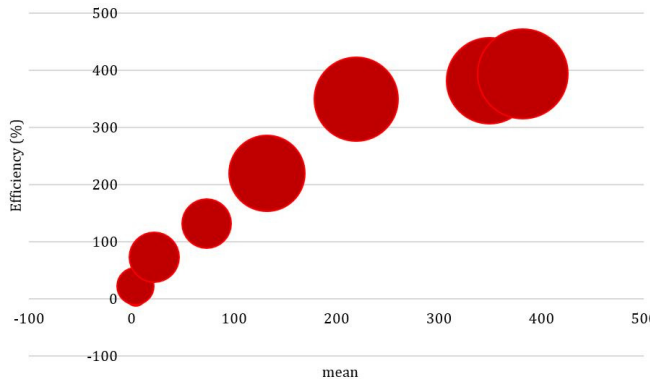


Fig. 10 Efficiency of ICT in Teaching

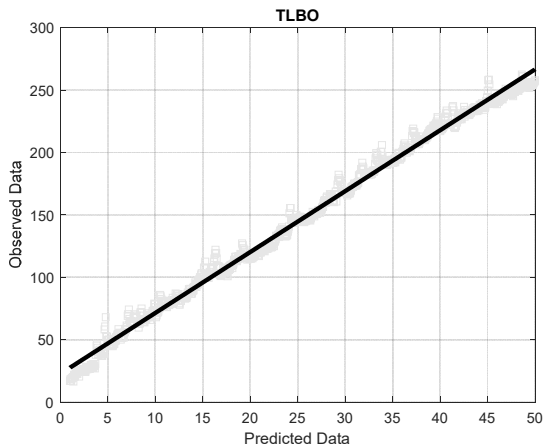


Fig. 11 Distribution of predicted and observed data using TLBO in test phase

data using TLBO in test phase. There is a good overlap between the regression line and noises (grey dots), showing the accuracy of our model. Fig. 12 shows the error plot of TLBO in test phase and Fig. 15 indicates the histogram of predicted values in test phase, in which the horizontal axis is the predicted values and the vertical line is the observed value. The maximum error is seen in 0-100 with 87 data and the least error is occurred in 400-500 with roughly 10 data. Fig. 14 shows the RMSE of TLBO in test phase in analyzing of the questionnaire results, showing a good overlap between two values and accuracy of TLBO in this analysis (close overlap between grey and blue waves). Fig. 15 shows the 3D plot of TLBO in its best performance in test phase. This model has shown an accurate analyze over the survey and questionnaire results in a minimal time in test phase than the train one.

Going through Table 1, the RMSE value of TLBO is

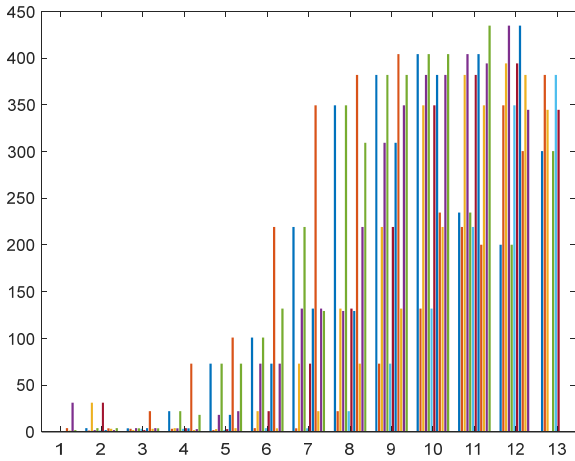


Fig. 12 Error plot of TLBO in test phase

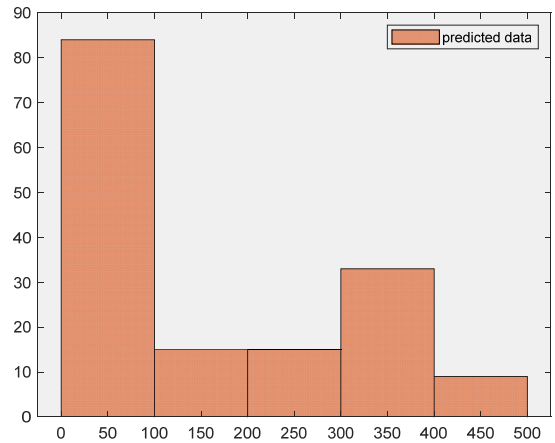


Fig. 13 Histogram of predicted values in test phase

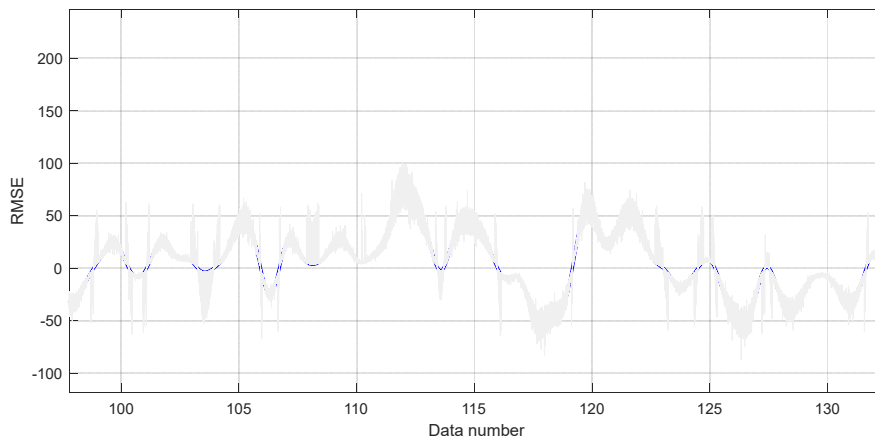


Fig. 14 The RMSE of TLBO in test phase in analyzing of the questionnaire results

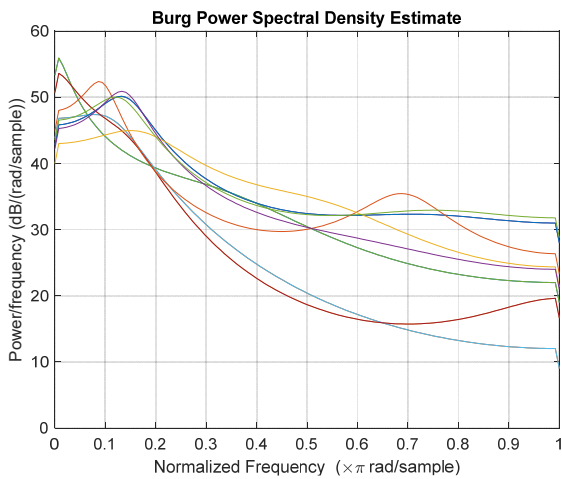


Fig. 15 Normalized data plot

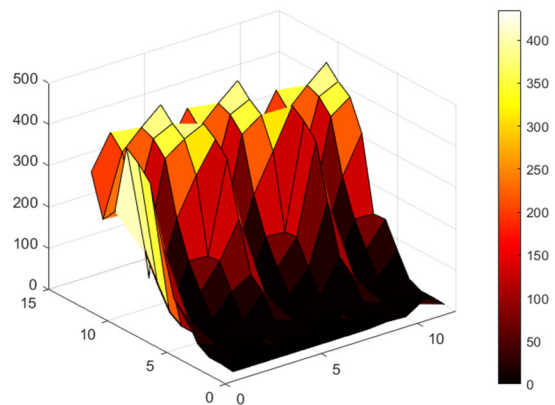


Fig. 16 3D plot of TLBO in its best performance

0.6786 in test phase and 0.7436 in train one, respectively. Therefore, the best RMSE of the model is closer to 0 in test phase, showing its better performance in test phase. Meanwhile, the RSQR value of the model is closer to 1 in its ideal case, then looking at the R^2 value of test phase with 0.9965, TLBO showed its best performance in this analysis.

Table 3 Train and test phase of TLBO

AI model	Testing phase		Train phase	
	RMSE	R^2	RMSE	R^2
TLBO	0.6786	0.9965	0.7436	0.9654

4. Conclusions

Smart learning environments highlight the need of adaptability and personalization based on atmosphere of learning, in addition to the notion of boosting learning. As a result, smart learning presents significant assessment issues since the material might not be fixed and the activity might be extended beyond formal and informal settings. Traditional design approach limits the student engagement to a consultative role. Traditional development employs a methodical research, design, and testing that does not necessitate the adoption of a specific user model. Users, on the other hand, are a valuable resource and may be involved in the design process to guarantee that technology is helpful and useable. The authors believe that the potential for smart learning is dependent on the architecture of the learning environment, and that it is critical to construct learning ecosystems through participatory procedures. Smart learning must promote the concept of ‘smart learners’ in contrast to the notion of the quantified student as a data item performed by algorithmic procedures. Feedback has long been seen as an important technique for assisting pupils in improving their performance. Traditional feedback is often related to the learners’ communication strategies with their professors and peers. As indicated in the preceding section, the use of technology opens new opportunities for tracking learners’ activities and providing them with more rapid feedback on their learning performance. Nevertheless, the majority of initiatives to apply learning analytics are focused on delivering information to teachers in order to improve their pedagogical approaches. Learners are rarely regarded as the primary recipients of learning analytics data, nor are they given the chance to utilize the data to reflect on their learning activity and self-regulate their learning more effectively. In response to the employment of learning analytics as a tool at the service of the institution, a growing number of experts have begun to push for student-centered analytics. In agreement with the literature, we believe that learning analytics may and should be utilized as a technique for reflecting and recognizing to enhance self-regulated learning. It is critical to identify the major problems in the design of learning environments that employ learning analytics to promote reflection. Transforming data into knowledge is a cognitive processing that could be aided by the manner in which data is made available. Information visualization has been acknowledged as a technique for sense-making since it aids in the synthesis of complicated information and promotes comparisons and conclusions (Zheng *et al.* 2021b). As a result, in order to really employ analytics to help learners in becoming independent learners, a student-centered strategy is required. Students in a smart learning environment would have multiple service options at various learning levels, where these services are supplied by different educational provisions either online or physically. Finally, substantial consideration should be given to the incorporation of ICT in the classroom to improve the competency of the country’s education system. This would help the raise of national education’s global ranking and develop a better future workforce. To promote the use of ICT in the classroom, the government must

develop and modify teachers’ beliefs about the integration of ICT in the classroom. Teachers play a critical role in ensuring that every new policy is applied quickly and successfully. The changes that are driven by improved technology and communication devices should be available to students at school or at home. Furthermore, instructors must be literate and have strong abilities and expertise in using ICT to enhance their teaching techniques and approach in order to implement good learning and satisfy the requirement for 21st century teaching skills.

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References

- Afrazi, M. and Yazdani, M. (2021), “Determination of the effect of soil particle size distribution on the shear behavior of sand”, *J. Adv. Eng. Computat.*, **5**(2), 125-134.
<http://dx.doi.org/10.25073/jaeca.202152.331>
- Ágnes, H.Z. (2004), “Hatékony tanulás”, *Új pedagógiai szemle*, **54**(12), 95-104.
- Albirini, A. (2006), “Teachers’ attitudes toward information and communication technologies: The case of Syrian EFL teachers”, *Comput. Edu.*, **47**(4), 373-398.
<https://doi.org/10.1016/j.compedu.2004.10.013>
- Aldrees, A., Bakheit, A.T. and Assilzadeh, H. (2021), “Intelligent estimation of the discharge peak in Al Aqiq drainage basin: A case study in Al Madinah Munwwarah region”, *Smart Struct. Syst., Int. J.*, **27**(6), 951-968.
<https://doi.org/10.12989/sss.2021.27.6.951>
- András, B. (2007), “Mobiltanulás és az egész életen át megszerezhető tudás”, *Világosság*, **9**, 21-28.
- Arnseth, H.C. and Hatlevik, O.E. (2010), “Challenges in aligning pedagogical practices and pupils’ competencies with the information society’s demands: The case of Norway”, In: *Cases on Interactive Technology Environments and Transnational Collaboration: Concerns and Perspectives*, IGI Global, pp. 266-280.
- Burbules, N.C. (2012), “El aprendizaje ubicuo y el futuro de la enseñanza”, *Encounters on education*, 13.
- Burbules, N.C. (2018), “8. Ubiquitous Learning and the Future of Teaching”, In: *Teacher Education in a Transnational World*, University of Toronto Press, pp. 177-188.
<https://doi.org/10.3138/9781442619999-012>
- Cao, Y., Alyousef, R., Jermsttiparsert, K., Ho, L.S., Alaskar, A., Alabduljabbar, H., Alrshoudi, F. and Mohamed, A.M. (2020), “Investigation on the monotonic behavior of the steel rack upright-beam column connection”, *Smart Struct. Syst., Int. J.*, **26**(1), 103-115. <https://doi.org/10.12989/sss.2020.26.1.103>
- Cao, B., Li, M., Liu, X., Zhao, J., Cao, W. and Lv, Z. (2021a), “Many-Objective Deployment Optimization for a Drone-Assisted Camera Network”, *IEEE Transact. Network Sci. Eng.*, **8**(4), 2756-2764. <https://doi.org/10.1109/TNSE.2021.3057915>
- Cao, B., Zhang, Y., Zhao, J., Liu, X., Skonieczny, Ł. and Lv, Z. (2021b), “Recommendation based on large-scale many-objective optimization for the intelligent internet of things system”, *IEEE Internet Things J.*, **1**.

- <https://doi.org/10.1109/JIOT.2021.3104661>
- Cao, B., Zhao, J., Lv, Z. and Yang, P. (2021c), "Diversified personalized recommendation optimization based on mobile data", *IEEE Transact. Intell. Transport. Syst.*, **22**(4), 2133-2139. <https://doi.org/10.1109/TITS.2020.3040909>
- Cao, B., Sun, Z., Zhang, J. and Gu, Y. (2021d), "Resource Allocation in 5G IoV Architecture Based on SDN and Fog-Cloud Computing", *IEEE Transact. Intell. Transport. Syst.*, **22**(6), 3832-3840. <https://doi.org/10.1109/TITS.2020.3048844>
- Cao, B., Gu, Y., Lv, Z., Yang, S., Zhao, J. and Li, Y. (2021e), "RFID Reader Anticollision Based on Distributed Parallel Particle Swarm Optimization", *IEEE Internet Things J.*, **8**(5), 3099-3107. <https://doi.org/10.1109/JIOT.2020.3033473>
- Cao, B., Zhang, W., Wang, X., Zhao, J., Gu, Y. and Zhang, Y. (2021f), "A memetic algorithm based on two_Arch2 for multi-depot heterogeneous-vehicle capacitated arc routing problem", *Swarm Evolut. Computat.*, **63**, 100864. <https://doi.org/10.1016/j.swevo.2021.100864>
- Chan, F.-M. (2002), ICT in Malaysian schools: Policy and strategies. a Workshop on the Promotion of ICT in Education to Narrow the Digital Divide.
- Chatti, M.A., Agustian, M.R., Jarke, M. and Specht, M. (2010), "Toward a personal learning environment framework", *Int. J. Virtual Personal Learn. Environ. (IJVPLE)*, **1**(4), 66-85. <https://doi.org/10.4018/jvple.2010100105>
- Chen, H., Miao, Y., Chen, Y., Fang, L., Zeng, L. and Shi, J. (2021), "Intelligent Model-based Integrity Assessment of Nonstationary Mechanical System", *J. Web Eng.*, **20**(2), 253-280. <https://doi.org/10.13052/jwe1540-9589.2022>
- Collis, B. (1996), "Tele-learning in a digital world: The future of distance learning."
- Cook, J., Pachler, N. and Bachmair, B. (2011), "Ubiquitous mobility with mobile phones: A cultural ecology for mobile learning", *E-learning and Digital Media*, **8**(3), 181-195. <https://doi.org/10.2304/2Felea.2011.8.3.181>
- Fang, Z., Lu, J., Liu, F., Xuan, J. and Zhang, G. (2021), "Open Set Domain Adaptation: Theoretical Bound and Algorithm", *IEEE Transact. Neural Networks Learn. Syst.*, **32**(10), 4309-4322. <https://doi.org/10.1109/TNNLS.2020.3017213>
- Finger, G. and Trinidad, S. (2002), "ICTs for learning: an overview of systematic initiatives in the Australian States and Territories", *Austral. Edu. Comput.*, **17**(2), 3-14.
- Ghanbari-Ghazijahani, T., Nabati, A., Azandariani, M.G. and Fanaie, N. (2020), "Crushing of steel tubes with different infills under partial axial loading", *Thin-Wall. Struct.*, **149**, 106614. <https://doi.org/10.1016/j.tws.2020.106614>
- Ghavifekr, S., Afshari, M. and Amla, S. (2012), "Management strategies for E-Learning system as the core component of systemic change: A qualitative analysis", *Life Sci. J.*, **9**(3), 2190-2196.
- Grabe, M. and Grabe, C. (2008), *Integrating technology for meaningful learning*, (5th Ed.), Houghton Mifflin Company, Boston, MA, USA.
- Gulbahar, Y. and Guven, I. (2008), "A survey on ICT usage and the perceptions of social studies teachers in Turkey", *J. Edu. Technol. Soc.*, **11**(3), 37-51.
- Guo, L., Ye, C., Ding, Y. and Wang, P. (2021), "Allocation of Centrally Switched Fault Current Limiters Enabled by 5G in Transmission System", *IEEE Transact. Power Delivery*, **36**(5), 3231-3241. <https://doi.org/10.1109/TPWRD.2020.3037193>
- Hermans, R., Tondeur, J., Van Braak, J. and Valcke, M. (2008), "The impact of primary school teachers' educational beliefs on the classroom use of computers", *Comput. Edu.*, **51**(4), 1499-1509. <https://doi.org/10.1016/j.compedu.2008.02.001>
- Hwang, G.-J. (2014), "Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective", *Smart Learn. Environ.*, **1**(1), 1-14. <https://doi.org/10.1186/s40561-014-0004-5>
- Ilma, K. (2011), "Az elektronikus tanulásról a 21. század első éveiben", Magánkiadás, Budapest, 150.
- Jahandari, S., Mohammadi, M., Rahmani, A., Abolhasani, M., Miraki, H., Mohammadifar, L., Kazemi, M., Saberian, M. and Rashidi, M. (2021a), "Mechanical Properties of Recycled Aggregate Concretes Containing Silica Fume and Steel Fibres", *Materials*, **14**(22), 7065. <https://doi.org/10.3390/ma14227065>
- Jahandari, S., Tao, Z., Saberian, M., Shariati, M., Li, J., Abolhasani, M., Kazemi, M., Rahmani, A. and Rashidi, M. (2021b), "Geotechnical properties of lime-geogrid improved clayey subgrade under various moisture conditions", *Road Mater. Pave. Des.*, 1-19. <https://doi.org/10.1080/14680629.2021.1950816>
- Jamieson-Proctor, R., Albion, P., Finger, G., Cavanagh, R., Fitzgerald, R., Bond, T. and Grimbeck, P. (2012), "Development of the TTF TPACK Survey Instrument", *Austral. Edu. Comput.*, **27**(3), 26-35.
- Jorge, C.M.H., Jorge, M.D.C.A., Gutiérrez, E.R., García, E.G. and Díaz, M.B. (2003), "Use of the ICTs and the Perception of E-learning among University Students: a Differential Perspective according to Gender and Degree Year Group", *Interactive educational multimedia: IEM*, pp. 13-28.
- Kazerani, S., Fanaie, N. and Soroushnia, S. (2017), "Seismic behavior of drilled beam section in moment connections", *Int. J. Numer. Methods Civil Eng.*, **1**(4), 1-6.
- Kim, T., Cho, J.Y. and Lee, B.G. (2012), "Evolution to smart learning in public education: a case study of Korean public education", *IFIP WG 3.4: Proceedings of International Conference on Open and Social Technologies for Networked Learning*, pp. 170-178. https://doi.org/10.1007/978-3-642-37285-8_18
- Kong, H., Lu, L., Yu, J., Chen, Y. and Tang, F. (2021), "Continuous Authentication Through Finger Gesture Interaction for Smart Homes Using WiFi", *IEEE Transact. Mobile Comput.*, **20**(11), 3148-3162. <https://doi.org/10.1109/TMC.2020.2994955>
- Koschmann, T. (1996), "Paradigm shifts and instructional technology: An introduction", *CSCL: Theory and practice of an emerging paradigm*, **116**, 1-23.
- Li, D., Togholi, A., Shariati, M., Sajedi, F., Bui, D.T., Kianmehr, P., Mohamad, E.T. and Khorami, M. (2019), "Application of polymer, silica-fume and crushed rubber in the production of Polymeric concrete", *Smart Struct. Syst., Int. J.*, **23**(2), 207-214. <http://doi.org/10.12989/sss.2019.23.2.207>
- Li, G.C., Sun, Y.T. and Qi, C.C. (2021), "Machine learning-based constitutive models for cement-grouted coal specimens under shearing", *Int. J. Min. Sci. Technol.*, **31**(5), 813-823. <https://doi.org/10.1016/j.ijmst.2021.08.005>
- Liu, K., Ke, F., Huang, X., Yu, R., Lin, F., Wu, Y. and Ng, D.W.K. (2021a), "DeepBAN: A Temporal Convolution-Based Communication Framework for Dynamic WBANs", *IEEE Transact. Commun.*, **69**(10), 6675-6690. <https://doi.org/10.1109/TCOMM.2021.3094581>
- Liu, L., Xiang, H. and Li, X. (2021b), "A novel perturbation method to reduce the dynamical degradation of digital chaotic maps", *Nonlinear Dyn.*, **103**(1), 1099-1115. <https://doi.org/10.1007/s11071-020-06113-4>
- Luo, G., Yuan, Q., Zhou, H., Cheng, N., Liu, Z., Yang, F. and Shen, X.S. (2018), "Cooperative vehicular content distribution in edge computing assisted 5G-VANET", *China Commun.*, **15**(7), 1-17. <https://doi.org/10.1109/CC.2018.8424578>
- Luo, J., Li, M., Liu, X., Tian, W., Zhong, S. and Shi, K. (2020), "Stabilization analysis for fuzzy systems with a switched sampled-data control", *J. Franklin Inst.*, **357**(1), 39-58. <https://doi.org/10.1016/j.jfranklin.2019.09.029>
- Lv, Z., Qiao, L., Hossain, M.S. and Choi, B.J. (2021), "Analysis of

- using blockchain to protect the privacy of drone big data”, *IEEE Network*, **35**(1), 44-49.
<https://doi.org/10.1109/MNET.011.2000154>
- Ma, Z., Zheng, W., Chen, X. and Yin, L. (2021), “Joint embedding VQA model based on dynamic word vector”, *Peer J. Comput. Sci.*, **7**, e353. <https://doi.org/10.7717/peerj-cs.353>
- Majedi, M., Afrazi, M. and Fakhimi, A. (2020), “FEM-BPM simulation of SHPB testing for measurement of rock tensile strength”, *Proceedings of the 54th US Rock Mechanics/ Geomechanics Symposium*.
- Mária, M.N. (2010), *Adaptív nevelés és oktatás, Magyar Tehetségsegítő Szervezetek Szövetsége*.
- Mehdizadeh, B., Jahandari, S., Vessalas, K., Miraki, H., Rasekh, H. and Samali, B. (2021), “Fresh, mechanical, and durability properties of self-compacting mortar incorporating alumina nanoparticles and rice husk ash”, *Materials*, **14**(22), 6778.
<https://doi.org/10.3390/ma14226778>
- Meng, F., Cheng, W. and Wang, J. (2021), “Semi-supervised Software Defect Prediction Model Based on Tri-training”, *KSIITransact. Internet Info. Syst.*, **15**(11), 4028-4042.
<https://doi.org/10.3837/tiis.2021.11.009>
- Miraki, H., Shariatmadari, N., Ghadir, P., Jahandari, S., Tao, Z. and Siddique, R. (2021), “Clayey soil stabilization using alkali-activated volcanic ash and slag”, *J. Rock Mech. Geotech. Eng.*
<https://doi.org/10.1016/j.jrmge.2021.08.012>
- Moghadam, H., Fanaei, N. and Motazedian, D. (2010), “Estimation of stress drop for some large shallow earthquakes using stochastic point source and finite fault modeling”, *Scientia Iranica*, **17**(3), 217-235.
- Mou, J., Duan, P., Gao, L., Liu, X. and Li, J. (2022), “An effective hybrid collaborative algorithm for energy-efficient distributed permutation flow-shop inverse scheduling”, *Future Generat. Comput. Syst.*, **128**, 521-537.
<https://doi.org/10.1016/j.future.2021.10.003>
- Nam, I., Souri, H. and Lee, H. (2015), “Percolation threshold and piezoresistive response of multi-wall carbon nanotube/cement composites”, *Smart Struct. Syst., Int. J.*, **18**(2), 217-231.
<http://doi.org/10.12989/sss.2016.18.2.217>
- Natividad, G., Mayes, R., Choi, J.-I. and Spector, J.M. (2015), “Balancing stable educational goals with changing educational technologies: challenges and opportunities”, *e-mentor*, (1 (58)), 83-94.
- Nowroozi, V., Hashemolhosseini, H., Afrazi, M. and Kasehchi, E. (2021), “Optimum Design for Soil Nailing to Stabilize Retaining Walls Using FLAC3D”, *J. Adv. Eng. Computat.*, **5**(2), 108-124. <http://dx.doi.org/10.25073/jaeca.202152.329>
- Qi, C., Xu, X. and Chen, Q. (2021), “Hydration reactivity difference between dicalcium silicate and tricalcium silicate revealed from structural and Bader charge analysis”, *Int. J. Minerals Metall. Mater.*, **29**, 335-344.
<https://dx.doi.org/10.1007/s12613-021-2364-5>
- Rouhanifar, S., Afrazi, M., Fakhimi, A. and Yazdani, M. (2021), “Strength and deformation behaviour of sand-rubber mixture”, *Int. J. Geotech. Eng.*, **15**(9), 1078-1092.
<https://doi.org/10.1080/19386362.2020.1812193>
- Sadeghian, F., Haddad, A., Jahandari, S., Rasekh, H. and Ozbakkaloglu, T. (2021a), “Effects of electrokinetic phenomena on the load-bearing capacity of different steel and concrete piles: A small-scale experimental study”, *Can. Geotech. J.*, **58**(5), 741-746. <https://doi.org/10.1139/cgj-2019-0650>
- Sadeghian, F., Jahandari, S., Haddad, A., Rasekh, H. and Li, J. (2021b), “Effects of variations of voltage and pH value on the shear strength of soil and durability of different electrodes and piles during electrokinetic phenomenon”, *J. Rock Mech. Geotech. Eng.* <https://doi.org/10.1016/j.jrmge.2021.07.017>
- Soman, R.N., Onoufrioua, T., Kyriakidesb, M.A., Votsisc, R.A. and Chrysostomou, C.Z. (2014), “Multi-type, multi-sensor placement optimization for structural health monitoring of long span bridges”, *Smart Struct. Syst., Int. J.*, **14**(1), 55-70.
<https://doi.org/10.12989/sss.2014.14.1.055>
- Spector, J.M. (2014), “Conceptualizing the emerging field of smart learning environments”, *Smart Learn. Environ.*, **1**(1), 1-10.
<https://doi.org/10.1186/s40561-014-0002-7>
- Taj, M., Khadimallah, M.A., Hussain, M., Khedher, K.M., Shamim, R.A., Ahmad, M. and Tounsi, A. (2020), “Analysis of nonlocal Kelvin’s model for embedded microtubules: Via viscoelastic medium”, *Smart Struct. Syst., Int. J.*, **26**(6), 809-817. <https://doi.org/10.12989/sss.2020.26.6.809>
- Wang, J., Zhao, G. and Zhang, H. (2009), “Optimal placement of piezoelectric curve beams in structural shape control”, *Smart Struct. Syst., Int. J.*, **5**(3), 241-260.
<https://doi.org/10.12989/sss.2009.5.3.241>
- Warwick, P. and Kershner, R. (2008), “Primary teachers’ understanding of the interactive whiteboard as a tool for children’s collaborative learning and knowledge-building”, *Learn. Media Technol.*, **33**(4), 269-287.
<https://doi.org/10.1080/17439880802496935>
- Wu, X., Zheng, W., Chen, X., Zhao, Y., Yu, T. and Mu, D. (2021a), “Improving high-impact bug report prediction with combination of interactive machine learning and active learning”, *Info. Software Technol.*, **133**, 106530.
<https://doi.org/10.1016/j.infsof.2021.106530>
- Wu, X., Zheng, W., Xia, X. and Lo, D. (2021b), “Data Quality Matters: A Case Study on Data Label Correctness for Security Bug Report Prediction”, *IEEE Transact. Software Eng.*, **1**.
<https://doi.org/10.1109/TSE.2021.3063727>
- Xie, W., Zhang, R., Zeng, D., Shi, K. and Zhong, S. (2020), “Strictly dissipative stabilization of multiple-memory Markov jump systems with general transition rates: A novel event-triggered control strategy”, *Int. J. Robust Nonlinear Control*, **30**(5), 1956-1978. <https://doi.org/10.1002/rnc.4856>
- Yahya, S., Ahmad, E. and Abd Jalil, K. (2010), “The definition and characteristics of ubiquitous learning: A discussion”, *Int. J. Edu. Develop. using ICT*, **6**(1).
- Yan, A., Hu, Y., Cui, J., Chen, Z., Huang, Z., Ni, T., Girard, P. and Wen, X. (2020), “Information Assurance Through Redundant Design: A Novel TNU Error-Resilient Latch for Harsh Radiation Environment”, *IEEE Transact. Comput.*, **69**(6), 789-799. <https://doi.org/10.1109/TC.2020.2966200>
- Yan, A., Fan, Z., Ding, L., Cui, J., Huang, Z., Wang, Q., Zheng, H., Girard, P. and Wen, X. (2021), “Cost-Effective and Highly Reliable Circuit Components Design for Safety-Critical Applications”, *IEEE Transact. Aerospace Electron. Systems*, **1**.
<https://doi.org/10.1109/TAES.2021.3103586>
- Yang, K.-T. and Wang, T.-H. (2012), “Interactive whiteboard: Effective interactive teaching strategy designs for biology teaching”, *E-Learning-Engineering, on-job training and interactive teaching*, pp. 139-156.
- Ye, S. and Ni, Y. (2012), “Information entropy based algorithm of sensor placement optimization for structural damage detection”, *Smart Struct. Syst., Int. J.*, **10**(4_5), 443-458.
https://doi.org/10.12989/sss.2012.10.4_5.443
- Young, S.S.-C. (2003), “Integrating ICT into second language education in a vocational high school”, *J. Comput. Assist. Learn.*, **19**(4), 447-461.
<https://doi.org/10.1046/j.0266-4909.2003.00049.x>
- Zhao, Y., Moayedi, H., Bahiraei, M. and Foong, L.K. (2020a), “Employing TLBO and SCE for optimal prediction of the compressive strength of concrete”, *Smart Struct. Syst., Int. J.*, **26**(6), 753-763. <https://doi.org/10.12989/sss.2020.26.6.753>
- Zhao, C., Zhong, S., Zhang, X., Zhong, Q. and Shi, K. (2020b), “Novel results on nonfragile sampled-data exponential synchronization for delayed complex dynamical networks”, *Int. J. Robust Nonlinear Control*, **30**(10), 4022-4042.

- <https://doi.org/10.1002/rnc.4975>
- Zhao, C., Zhong, S., Zhong, Q. and Shi, K. (2020c), "Synchronization of Markovian complex networks with input mode delay and Markovian directed communication via distributed dynamic event-triggered control", *Nonlinear Anal.: Hybrid Syst.*, **36**, 100883.
<https://doi.org/10.1016/j.nahs.2020.100883>
- Zhao, C., Liu, X., Zhong, S., Shi, K., Liao, D. and Zhong, Q. (2021a), "Secure consensus of multi-agent systems with redundant signal and communication interference via distributed dynamic event-triggered control", *ISA Transact.*, **112**, 89-98.
<https://doi.org/10.1016/j.isatra.2020.11.030>
- Zhao, S., Li, F., Li, H., Lu, R., Ren, S., Bao, H., Lin, J.H. and Han, S. (2021b), "Smart and practical privacy-preserving data aggregation for fog-based smart grids", *IEEE Transact. Info. Forensics Security*, **16**, 521-536.
<https://doi.org/10.1109/TIFS.2020.3014487>
- Zheng, W., Liu, X. and Yin, L. (2021a), "Research on image classification method based on improved multi-scale relational network", *Peer J. Comput. Sci.*, **7**, e613.
<https://doi.org/10.7717/peerj-cs.613>
- Zheng, W., Yin, L., Chen, X., Ma, Z., Liu, S. and Yang, B. (2021b), "Knowledge base graph embedding module design for Visual question answering model", *Pattern Recogn.*, **120**, 108153. <https://doi.org/10.1016/j.patcog.2021.108153>
- Zhou, W., Guo, Q., Lei, J., Yu, L. and Hwang, J.N. (2021), "IRFR-Net: Interactive recursive feature-reshaping network for detecting salient objects in RGB-D images", *IEEE Transact. Neural Networks Learn. Syst.*, 1-13.
<https://doi.org/10.1109/TNNLS.2021.3105484>
- Zhou, Y., Xu, G., Tang, K., Tian, L. and Sun, Y. (2022), "Video coding optimization in AVS2", *Info. Process. Manage.*, **59**(2), 102808. <https://doi.org/10.1016/j.ipm.2021.102808>
- Zhu, Z.-T., Yu, M.-H. and Riezebos, P. (2016), "A research framework of smart education", *Smart Learn. Environ.*, **3**(1), 1-17. <https://doi.org/10.1186/s40561-016-0026-2>