Journal of System Management (JSM)
Online ISSN: 2538-1571
Print ISSN: 2322-2301
Vol. 7, No. 3, (27) 2021, pp. 1-34
Research Paper

Application of Adaptive Neuro-Based Fuzzy Inference System to Evaluate the Resilience of E-learning in Education Systems, During the Covid-19 Pandemic

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Abstract **Education systems in the world are enduring COVID-19 induced perturbations and consequences. Given the growing use of E-learning during COVID-19 epidemic and expansion of Internet-based infrastructure, the need for a resilient approach to e-learning systems is deeply felt. This paper aims to address the issue of how to provide a model for evaluating the resilience of E-learning in Iranian virtual universities during the outbreak of coronavirus employing an Adaptive Neuro-Based Fuzzy Inference System (ANFIS). In the present paper, 5 substantial factors including individual, assessment and support, content, agility, and technology were identified as inputs, and e-learning resilience was considered as single output. Moreover, ANFIS was employed to model the resilience of E-learning systems. Findings revealed almost medium to low degree of resilience for the e-learning system established in Iran's virtual university. Statistical analysis demonstrated that there was no meaningful difference between experts' opinions and our proposed procedure for E-learning resilience measurement. The proposed model showed significant sensitivity to changes in agility. Therefore, agility should be considered as the first priority in achieving the desired level of resilience for the e-learning systems of the Iranian virtual university.**

Keywords *E—learning, Resiliece,COVID-19, Adaptive Neuro-Based Fuzzy Inference System, Virtual University*

Received: 24/08/2021 Accepted: 23/11/2021

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Introduction

The post-coronavirus world will look different from what we are witnessing these days. Humans have come to experience a more useful face of innovative technologies in the era of fighting the coronavirus. The virus is not only a major health crisis; it is indeed changing the structure of global order in business and economy (McKenzie, 2020). Without the use of Internet-based technologies, social distancing, quarantine, lockdown, health consultation, social awareness, humanitarian logistics, etc. as the main constituents of standard health protocols during COVID-19 outbreak would be ineffective in and damaging to the economic, social, and educational sectors. Therefore, improvement of resilience can be one factor in mitigating the unfavorable effects and severity of disorders and disturbances caused by coronavirus disease outbreak. According to Provitolo et al. (2017), during this event, in a broader sense, resilience may correspond to the capacity to resist and cope with a shock and absorb a shock, which involves a certain degree of flexibility. Before the shock, resilience represents three capabilities; to anticipate unpredictable and inconceivable scenarios to ensure operational capacity and functionality of systems and organizations, even in the “damaged mode”; to manage or preserve the essential functions, structures, and organizations to adapt them to future uncertain situations (anticipative adaptation); to learn. Further to the above, after the shock, resilience reveals the following; the capacity to recover and rebuild, here or elsewhere, which mobilizes a system’s internal and/or external resources, whether it is an individual, a neighborhood, a town, a country, etc.; a system’s capacity to maintain its integrity and return (or bounce back) to either the former state of equilibrium or a new state; an individual or community’s capacity to adapt, take advantage of a negative situation, and renew and transform the system. Managing the network structure plays a key role in its resilience, and a strategic and operational plan is required to increase the capacity of a system to cope with critical situations (Jassbi et al., 2015; Ivanov, 2018).

Background

Nowadays, with a rapid growth of multimedia systems and networking technologies, Internet-based learning, and widespread learning methods, traditional learning is also shifting to virtual learning environments (Moreira, Pereira, Dora and Ferreira, 2018). As one of the technological tools, E-learning improves the education process (Nazari farokhi. et al, 2020). E-learning is described as delivery of learning and knowledge through technology and the internet (Gros et al., 2016; Hong et al., 2017; Aljawarneh 2020). E-learning is defined as a system built upon technology, organization, and management that gives students necessary abilities to learn online and facilitate their learning in this process (Bonder, Anastasio, Anzer and Brocki, 2016). The Open and Distance Learning Quality Council of the UK defined E-learning as "an effective learning process created by combining digitally delivered content with (learning) support and services". In fact, the possibility of distance learning and knowledge sharing through the Internet is facilitated by E-learning with hardware infrastructure and software programs. Expansion of new methods for learning and teaching in educational institutions and subsequently, the flexibility of the learners and teachers were improved by the development of ICT in education (Naqshbandi et al., 2017). Wu and Zeshan (2020) assessed the effectiveness of e-learning as well as the perceived satisfaction of students who took online courses in lieu of traditional in-person medical education. Taking into account all the features and types of hardware and software, e-learning pushes human knowledge to the edge of a significant education transformation. In some countries, educational institutions have been suspended under regulations to combat the spread of coronavirus. According to UNESCO (2020), "The COVID-19 pandemic has caused the most severe disruption to global education systems in history, forcing more than 1.6 billion learners in more than 190 countries out of school at the peak of the crisis. It threatens the future of a generation with 24 million children and youth at risk of dropping out".

This phenomenon exerts an unprecedented overwhelming impact on the global education system. Without the use of ICT and e-learning in the educational process and subsequently, the ongoing learning suspension, there would be harmful consequences in terms of education and society. Azlan et al. (2020) found that students could adapt to new norms of education through e-learning despite their preference for face-to-face education. Challenges such as practical irreplaceability and clinical experience, distractions, lack of interaction, mental stress, poor internet connectivity, and limited data applications were addressed by Azlan et al. (2020). Almulhim et al. (2020) evaluated the impact of e-learning on medical students and their outlook on this dramatic shift. Addressing how the Internet has proved to be robust in successfully coping with challenges while maintaining university operations, Favale et al. (2020) presented a snapshot of abrupt changes observed in campus traffic due to COVID-19. Drawing on findings by Shingal (2020), salient features of the post-COVID-19 new education model, areas to be considered, and various e-learning techniques have been studied, as listed in Table 1.

Table 1
Post-COVID-19 New Education Model and Required Technologies

Salient features	The focus	Various techniques for e-learning	Some of the post pandemic era technology development requirements
Post-COVID-19 mobile learning/distance learning will flourish	Developing experiential learning material for online classes.	Distance learning	Developing lectures Studios, equipping educators and students with necessary digital gadgets, providing software training, and above all, providing strong Internet infrastructure.
Experiential learning will become more widespread	Learning/teaching cases for case studies	Correspondence learning	A crucial requirement of educating all stakeholders about the importance of e-learning. Unless each stockholder from the highest to lowest level understands the importance of imparting online education, the new education model will not become resilient.
Social media will emerge as important platforms for information exchange among teachers, educators, parents, students, and educational institutes.	Simulation games to explain concepts	Learning from home	A strong need for redefining the role of educators as the co-creator of knowledge involved in co-learning and as an active participator, thus evolving into a new model of education system.
More emphasis on the study through simulation tools, case studies,	Role-playing demonstrating models	Massive online open courses	Redefining the role of students so that they become actively involved in teaching-

Salient features	The focus	Various techniques for e-learning	Some of the post pandemic era technology development requirements
stories, and examples will be done.			learning process, help educators to design curriculum as per their interest, and give feedbacks and suggestions to make experience of online learning better for everyone. They need to be an active co-creator of knowledge rather than being a mere passive receptor who used to sit on last benches and listen the teachers inactively.
	Story-based examples, questionnaire, and group discussions	Learning through interactive TV channels	Providing necessary skills and familiarization of students, educators, and parents with online protocols/decorum, discipline, life skills, and conventions/procedures to make online learning a rich experience for everyone.
	Development of interactive online content to keep students engaged.	Video applications such as Youtube, Vimeo, etc.	Providing basic knowledge and training to students, teachers, educators, principals, and management of educational institutes alike; they are able to tap into new technology.
	Development of a standard common interface for all users which is safe, secure, and convinient.	Learning through apps such as Byjus, Unacademy, Udemy, Lynda, etc.	

Salient features	The focus	Various techniques for e-learning	Some of the post pandemic era technology development requirements
		Learning through e-content blogs, articles, and pdf notes	
		Self learning through e-books and other digital content	
		Listening audiobooks	
		The live meeting apps such as Google Classroom, Google Meet, Zoom, Cisco Webex, Microsoft team, etc.	

Fig. 1 shows the framework of e-resilience in education (van de Laar, 2020). The circles demonstrate four fitting and interactive levels and shape the e-resilience of the education systems after a shock. Dark blue, purple, green, and pink represent individual, program, institutional, and macro levels, respectively. At the central and macro level, the country ecosystem of digital education is found. Crucially, e-resilience of national education depends on the country's internet coverage. Connectivity represents a significant variation across countries. For a more detailed study, readers are highly recommended to refer to van de Laar (2020).

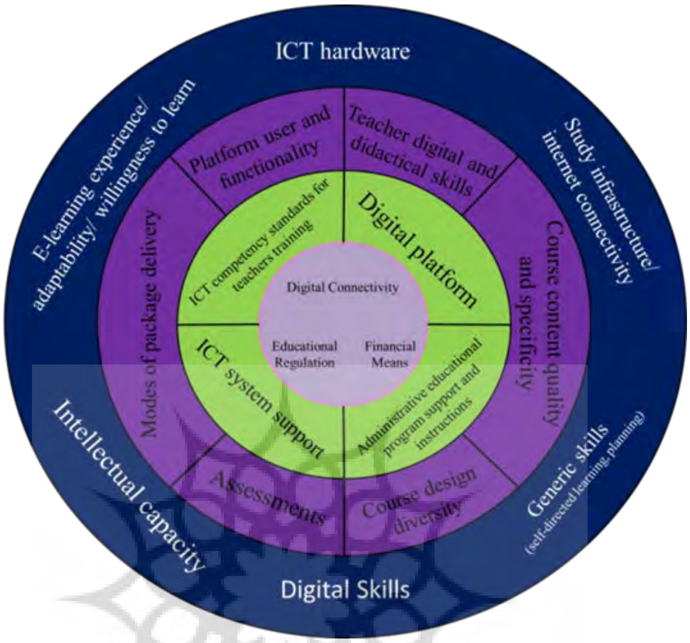

Figure 1
E-learning Resilience in a Higher Education Framework

Proposed Model for Measurement of E-learning Resilience During COVID-19 Pandemic

Artificial Neural Network (ANN) exploits a biological process-based computational method to solve complex problems that are too tedious for humans or computers to handle (Gill et al., 2017). ANNs are computational networks that attempt to simulate the networks of nerve cell (neurons) of the biological (human or animal) central nervous system in a gross manner. They are assumed to be black-boxes due to the sets of outputs and inputs (Gill et al., 2017). Also, they can be adapted to a wide range of situations with no previously proposed mathematical equation or model (Seyedhoseini et al., 2010). Common understanding of most physical processes rests largely on imprecise human reasoning. The ability to embed such reasoning in hitherto intractable and complex problems is the criterion by which the efficacy of fuzzy logic is judged.

Fuzzy set theory is a perfect tool to model uncertainty and imprecision arising from mental phenomena. Fuzzy Inference Systems (FISs) are one of the most applied and popular systems developed for fuzzy reasoning which uses fuzzy logic for modeling uncertainty. There are several inference techniques developed for fuzzy rule-based systems in the literature (Mamdani, 1977; Takagi and Sugeno, 1985). Mamdani FIS is the first inference methodology, in which inputs and outputs are represented by fuzzy relational equations in the canonical rule-based form. In Sugeno FIS, output of the fuzzy rule is characterized by a crisp function. Study of Radfar et al. (2011) is highly recommended, as the FIS employed is neither random nor stochastic. Adaptive network-based fuzzy inference is a combination of two soft-computing methods of ANN and fuzzy logic (Jang, 1993). ANFIS architecture is an adaptive network that uses supervised learning on learning algorithm, which has a function similar to the model of Takagi–Sugeno fuzzy inference system (Suparta and Alhasa, 2016). Each node in this network has different functions and tasks, and the output depends on the incoming signals and parameters that are available in the node (Suparta and Alhasa, 2016). A learning rule could affect the parameters in the node and reduce the occurrence of errors in the output of the adaptive network (Jang, 1993). In this research, three methods of documentation, Delphi, and survey were applied to collect information. In other words, the method enjoys a kind of triangulation. In order to gather the needed information for establishing the theoretical foundations of research and forming a conceptual model, the documentary and library method as well as the latest scientific articles and books related to the resilience of e-learning were used. Also, for refining and finalizing the components of resilience to design the proposed conceptual model, the fuzzy Delphi technique was applied in line with the consensus of experts. The steps of designing the resilience model of e-learning services based on preliminary study, resource search, and interviewing with experts for the implementation of the model are shown in Figure 2.

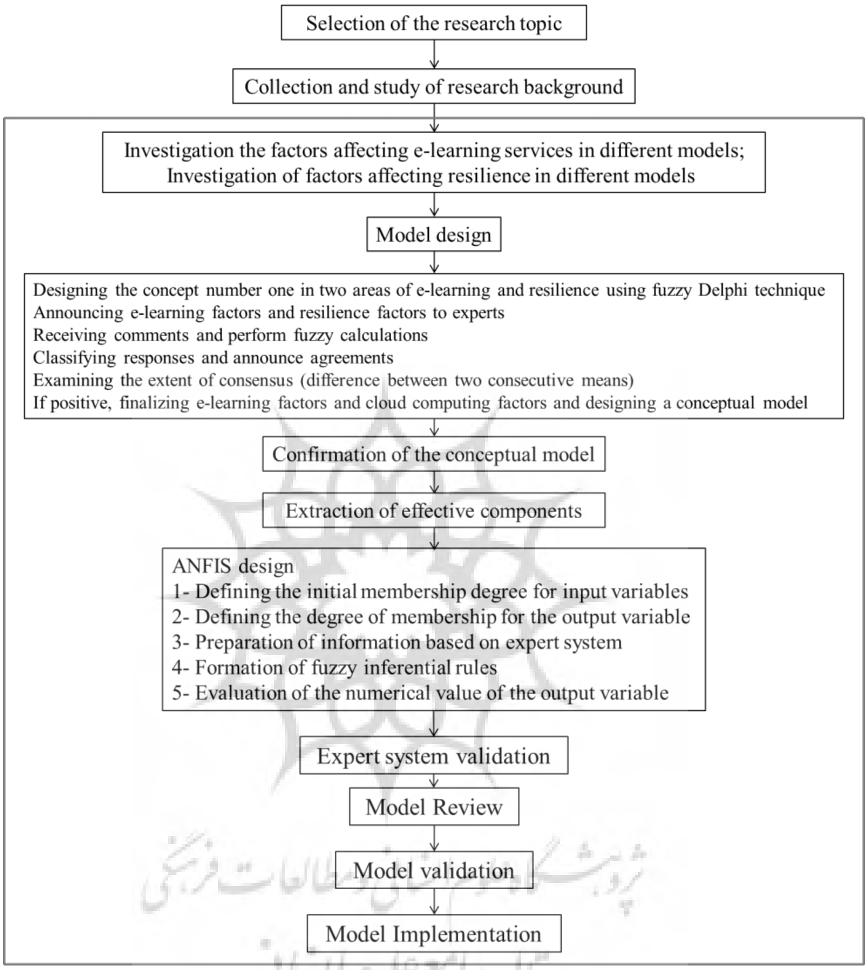

Figure 2
The Process of E-learning Resilience Evaluation Based on ANFIS

The basis for designing a resilience evaluation model of e-learning systems was determined upon identifying the main indicators of resilience enablers, the relevant sub-indicators based on the existing literature, and the knowledge of experts (decision group). According to Table 2, 22 indicators in 5 categories including individual, assessment and support, content, agility, and technology factors were obtained.

Table 2

Indicators Related to Resilience and E-learning

Factor	Sub-factor	Selected quote	Ref.
Individual Factors	Change ready	"As both learning and teaching could be conducted online when e-learning is adopted, learners' acceptance is necessary and their change in behavior is also essential to expressing their readiness" (The and Usagawa, 2018).	Chang-Richards et al. (2013) Ayebi-Arthur (2015)
	Leadership situation awareness	"…the management team decided that the university website would become the central port for official information for the UC community" (Dabner, 2012, p. 73). "…lecturers who had identified the loss of physical space as the most pressing problem sought to replicate the face-to-face experience in the online environment" (Learning Resources Working Group, p 22).	
	Staff engagement	"There was also huge relief from College of Education lecturers who already had Flexible Learning Option (FLO) courses running and just needed to add study guides online and direct on-campus students to their Learn sites" (Learning Resources Working Group, 2013-2017).	
	Proactive posture	A strategic business review of blended learning developments within and across colleges (Learning and Teaching Plan, 2013-2017).	
Technology factors	Technology innovation	"lots of staff did few videos using a webcam on a laptop and posting them on Learn"; so, students could hear and see them	Adedoyin & Soykan (2020)

Factor	Sub-factor	Selected quote	Ref.
		as they would in a face-to-face class (Ayebi-Arthur, 2015).	
	Compatibility in using cloud computing	"The IT infrastructure may be made more resilient by decentralization of services and hosting some applications utilizing Cloud computing" (Ayebi-Arthur, 2015). "However, cloud computing can be contentious because it has implications for security and control of sensitive data" (Ayebi-Arthur, 2015).	Miller (2008); Low et al. (2011); Borgman et al. (2013); Carroll et al. (2011); Fortis,et al. (2012); Leavitt (2009); Chellappa (1997)
	Cloud security	Active state against threats improves the effective system of organizational resilience, identifying the vulnerabilities of units and activities and measures related to accident prevention, preparedness, and response (McManus, 2008; Mendoca and Wallace, 2015).	Carroll et al. (2011); Fortis et al. (2012); Wood & Anderson (2011); Chebroula (2011); Dargha (2012; Leavitt (2009**)**
	Ability to reconfigure	"A request must be made for the online resources from the publishers and the ezproxy server reconfigured again in order to allow off-campus access to the resources from the publishers" (P. Kennedy, personal communication, August 27, 2015).	Teece (2018)
	Continuous integration	"The skills and knowledge that teachers need to have differ depending on the perceived purpose and anticipated impact of technology integration in the curriculum"(Low et al., 2011).	Andres et al. (2015)
Content factors	Interactivity	"Learners tended to have a kind of conversation in a self-directed e-learning environment by means of scaffolding, but without any help from tutors" (Meri, 2015). "...that kind of interaction supported learners to have or	Benigno and Trentin (2000); Meyen et al. (2006).

Factor	Sub-factor	Selected quote	Ref.
		improve the ability to manage and handle their learning" (Meri, 2015).	
	Being up to date	"The University of Canterbury set up a website, UC Re-start, that kept staff and students up to date with all the latest announcements and information relating to the 4th September earthquake and UC's re-opening" (Ayebi-Arthur, 2015).	Shee and Wang (2008); Ozkan and Koseler (2009); Delone and McLean (2003).
	Risk management and risk sharing culture	"Communication can contribute to the empowerment of citizens in crisis situations by supporting preparedness, enhancing societal understanding of risks, and increasing cooperation" (Vos et al., 2011).	Li and Zobel (2020)
Agility factors	Redundancy	"the redundancy effect occurs under conditions in which different sources of information are intelligible in isolation and when both sources provide similar information, but in a different form" (Kalyuga et al., 2000). "multimedia learning situations in which presenting words as text and speech is worse than presenting words solely as speech" (Mayer et al., 2001).	Xu et al. (2020); Dixit et al. (2020)
	Transparency	'The potential of social networking lies within transparency and the ability to create awareness among students' (Dalsgaard and Paulsen, 2009).	Kamalahmadi and Parast (2016)
	System access speed	The requirements are growing more acute due to the training requirements from users and the need to increase the speed of information sharing. E-teacher competences including technical or media literacy, teaching skills,	Selim (2007); Govindasamy (2002)

Factor	Sub-factor	Selected quote	Ref.
		methods, and skills in the educational domain need to be diversified (Oprea, 2014).	
	Internet speed and bandwidth	A Technology Survival Guide for Online Learning Developed by the Temple College eLearning Department (Version 1.13)	Selim (2007) Govindasamy (2002)
	Flexibility	Ability to adapt to change and ability to adapt organizational resilience programs and policies to environmental uncertainty (McManus, 2008; Limnios et al., 2014).	Kim et al. (2015) Giannoccaro and Iftikhar (2019)
Assessment and support factors	Network collaboration	"...E-Learning requires a wider network of collaboration among all professionals involved (instructors, instructional designers, technology support staff, etc.)" (Vandenhouten et al., 2014)	Lee and Zobel (2020); Dixit et al. (2020)
	Stress testing plan	"The IT servers of the Faculty of Commerce, which contained all the teaching and research files of academic staff, became inaccessible" (Ayebi-Arthur, 2015).	Ayebi-Arthur (2015)
	Support for peer networks	"Peer-to-peer communications through social media such as social networking sites, text and instant messaging applications, blogs, wikis, and other web forums were growing as a means of supporting additional, often critical and accurate, dissemination of information within the public sphere".	Oliveira et al. (2014)
	Financial and legal support	The legal changes may be required in terms of IPR ownership and the associated relationships between those connected with IPR. This may involve the use of an updated contract of employment in	Benigno and Trentin (2000) Frydenberg (2002)

Factor	Sub-factor	Selected quote	Ref.
		relation to new staff, renegotiation of terms of existing contracts, use of ad-hoc agreements with staff and students in relation to particular activities or projects, and review of procurement terms and conditions. Legal consequences of adopting an open educational resources approach should be considered according to updated and latest legal rules (Mehrpouyan and Khadem razavi, 2014).	
	Network learning	Goodyear and Carvalho (2014) suggested that instructional designers should have a repertoire of broad knowledge of epistemological, pedagogical, social, and psychological principles as well as interface design experience to create effective networked learning environments (Czerkawski, 2015).	Makkonen et al. (2013) Pavlou and ElSawy (2011)

Therefore, a model for resilience of e-learning system assessment employed in this research is shown in Figure 3. In order to assess the validity of the model, the proposed model was presented along with a questionnaire consisting of open and closed questions to a number of experts in the field of resilience of e-learning systems; their approvals were evaluated and their points of view were obtained step by step. Then, necessary modifications to the conceptual model of the research were made. The process of making changes continued until reaching convergence among experts. According to the results of the final perspectives and the use of statistical techniques, the validity of the conceptual model was investigated.

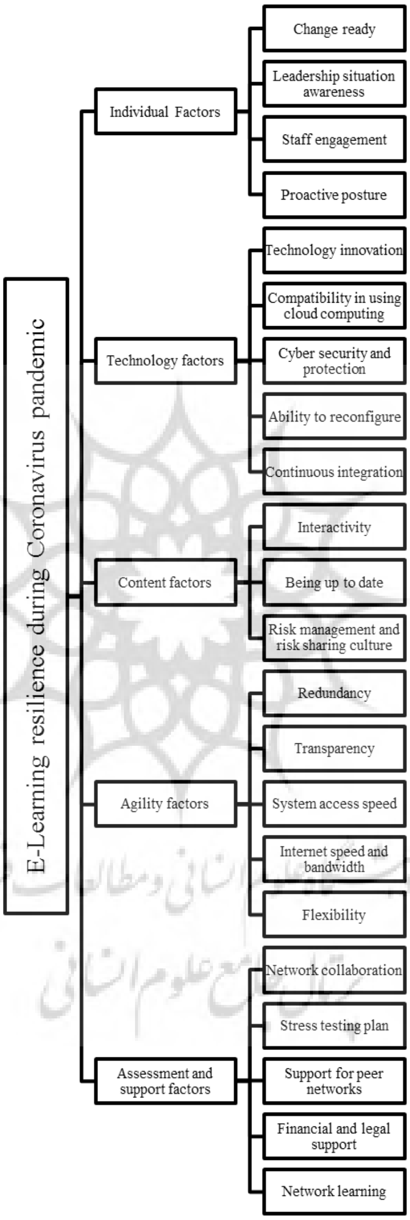

Figure 3
E-learning System Resilience Assessment Model

According to Figure 4, the main ANFIS is designed to evaluate the resilience of e-learning. İnput layer consists of individual, technology, assessment and support, content, and agility factors and resilience capability of e-learning system is the output. The hidden layer includes fuzzy operator, application method, aggregation of all outputs, and defuzzification.

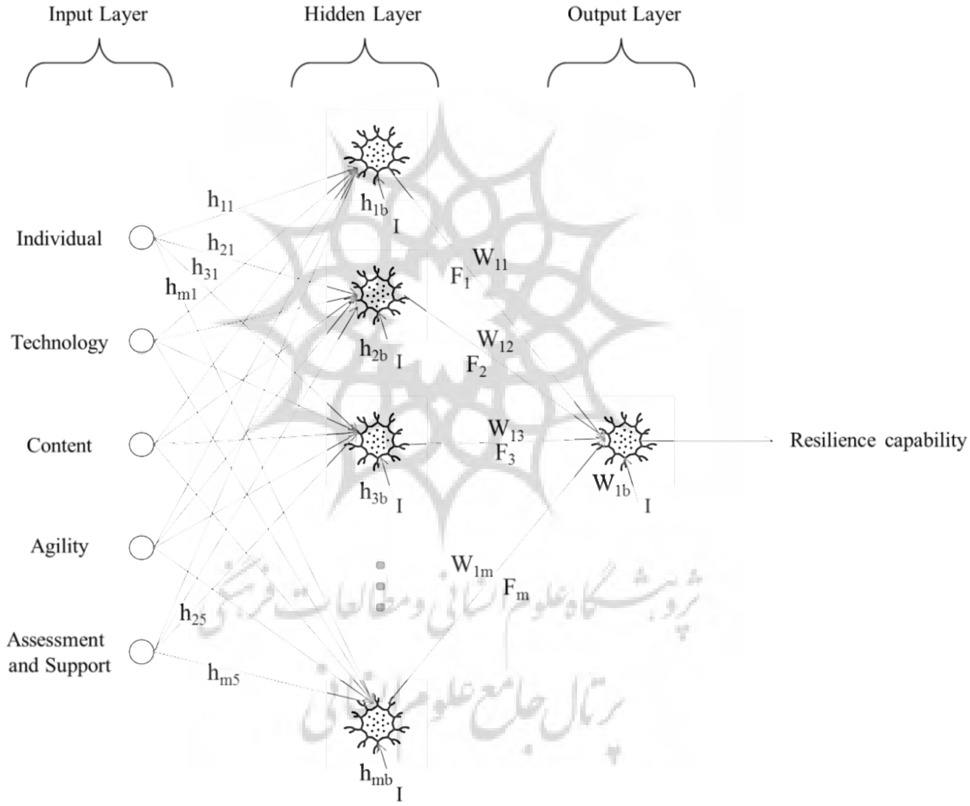

Figure 4
ANFIS Architecture

For example, individual factors have these four inputs: change ready (IF1), leadership situation awareness (IF2), staff engagement (IF3), and proactive posture (IF4). Figure 5 illustrates the FIS view of individual factors.

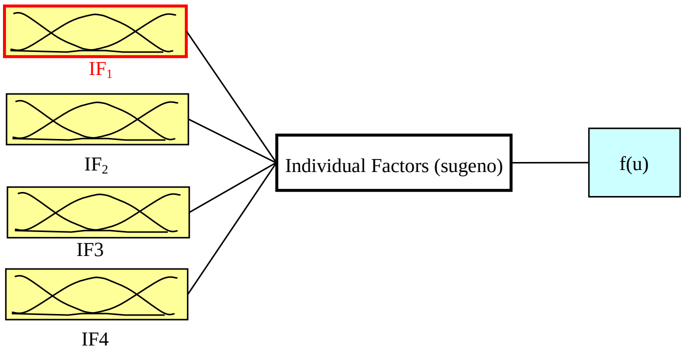

Figure 5
FIS view: Individual Factors

Model implementation

In order to evaluate the resilience of the e-learning system, we need to implement the presented model in a practical environment and achieve the results obtained from the implementation of the proposed model. To this end, the authors have investigated virtual university in Iran. In recent years, attempts at online university studies have multiplied at graduate and postgraduate levels (Herrera-Pavo, 2021). There are 23 units of virtual universities in Iran that generally accept undergraduate and graduate students. On the other hand, following the outbreak of Coronavirus disease, all of the educational units were closed based on the Iranian government instructions. Despite the recent closures, two basic measures have been taken to protect the educational process: (a) developing “SHAD” application to primary, secondary, and high schools as well as (b) launching educational systems by universities across the country. Allocating a certain portion of Internet traffic for free to students, teachers, and professors and developing passive defense infrastructure, etc., remain two taken measures of the resilient proceedings during the outbreak of Coronavirus in Iran. In this research, the Gaussian function category has been employed to define the input and output variables for the fuzzy inference system. The range of changes in input and output variables is also defined between 0 and 10.

By structuring fuzzy inference rules to extract experts' knowledge, a questionnaire containing a combination of different values for input variables was prepared. Figure 6 shows the membership function of the linguistic variables of the inputs and outputs in the fuzzy inference system for resilience evaluation. Different values are generated randomly and experts are asked to judge the input and output variables based on practical knowledge and actual experience, taking into account these generated values. In this research, subtractive clustering method has been used to form the structure of inferential rules with a fast and one-pass algorithm for estimating the number of categories and data centers in a dataset. In the present study, the influence factor, acceptance ratio, and reject ratio have values of 0.15, 1.25, and 0.5 according to the subtractive clustering process.

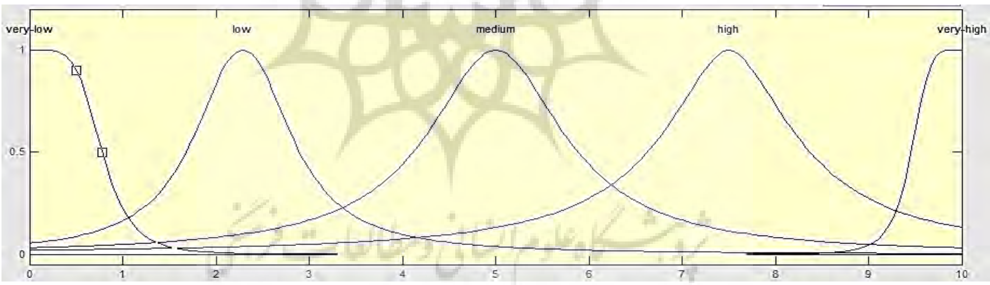

Figure 6
The Membership Function

Two available methods that can adjust the membership degree parameters to the fuzzy inference system training include back-propagation and hybrid methods. In the back-propagation method, by using the descending slope of error, the error value is distributed to the inputs and the parameters are corrected. This training method functions exactly the same as the error propagation method used in neural networks. It is clear from the structure of ANFIS network that the total output can be written as a linear combination of result parameters. To design the ANFIS system presented in this paper, an optimal training method, i.e., the same hybrid methods, was used. Error Tolerance (ET) was employed to determine a criterion for stopping training directly related to the magnitude of the error. Designed ANFIS with 70 Epochs achieved an acceptable rate of error. Table 3 shows the error rate in ANFIS and Sub-ANFIS after 70 training Epochs.

Table 3
Error Rate in ANFIS

	ANFIS	**Error**
1	Individual (IF)	$1.25 * 10^{-2}$
2	Technology (TF)	$1.37 * 10^{-2}$
3	Content (CF)	$6.4 * 10^{-2}$
4	Agility (AF)	$3.7 * 10^{-2}$
5	Assessment and support (SF)	$5.3 * 10^{-2}$
6	Resilience of e-learning (RE)	$1.8 * 10^{-2}$

The defuzzified value (crisp) of resilience was calculated as 3.41; by matching this value with the defined membership function (Figure 6) for the fuzzy inference system, the initial resilience of the e-learning system of Iran's virtual university can be assessed by almost medium to low degrees of resilience. In the following, a three-dimensional diagram is given for further interpretation. The decision level of this type of charts is created using the designed ANFIS. Figure 7 illustrates a three-dimensional view of individual indicator, where the length and width of the curve are two inputs of individual factor, namely change ready and proactive posture. These types of surfaces are structured in such a way that the effect of binary values of input variables on the output component is clearly exhibited. Of note, in case where the change ready and proactive posture factors are zero, the individual level has a non-zero value due to the effects of other factors.

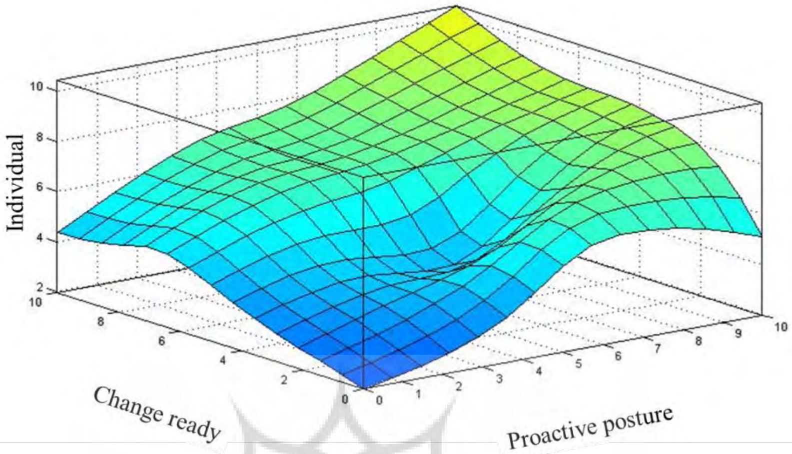

Figure 7
İndividual Surface Considering Change Ready and Proactive Posture as Inputs

Validation and Verification of ANFIS Model

In order to validate the designed model, the information extracted from experts' knowledge and judgment on the output variable of ANFIS (under different values of its inputs) is divided into three categories: training data, testing data, and checking data. The training data include the input vector of the "input/output" data, which models the target system by the hybrid training technique (combination of descending gradient and least error squares). In this regard, error tolerance is used to set an objective, that is, to stop training when it directly corresponds to the size of the error. Training stops when training data error is within the defined error range. Training error is calculated through Root-Mean-Square Deviation (RMSD). In this paper, Mean Magnitude of Relative Error (MMRE) is considered a criterion for model validation. According to the subtractive clustering process, the influence factor, squash factor, acceptance ratio, and reject ratio are characterized by values of 0.5, 1.25, 0.5, and 0.15, respectively. The hybrid method has been used for ANFIS training. Error tolerance is employed to determine a criterion for stopping training that is directly related to the size of the error. The ANFIS designed in this study achieved an acceptable error rate with 70 training courses (EPOCH). The trend of errors associated with the designed ANFIS was investigated; for example, Figure 8 shows the trend of reducing the training data errors in return for increasing EPOCH.

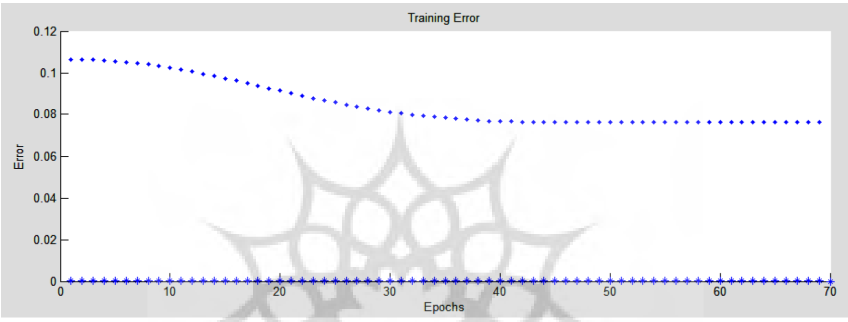

Figure 8
Trend of Error Changes

Figure 9 clearly demonstrates the consistency between the training and checking data sets.

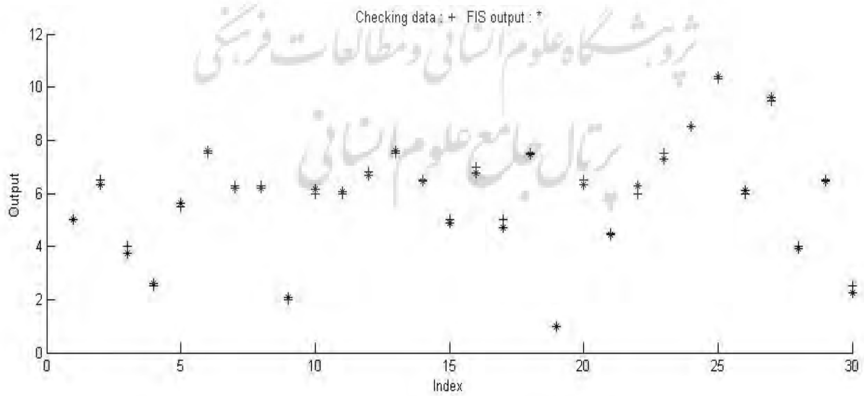

Figure 9
Comparison Chart Between ANFIS Output and Checking Data

In this diagram, asterisk and plus signs denote the output of the system and the checking data, respectively, which are almost consistent, thus demonstrating the absence of over-compliance in the designed ANFIS. ANFIS Output Comparison Chart ANFIS test data designed to evaluate resilience enablers are shown in Figure 10. The asterisk symbol indicates the ANFIS output and the circle symbol shows the testing data. The average error calculated in this ANFIS is 0.056.

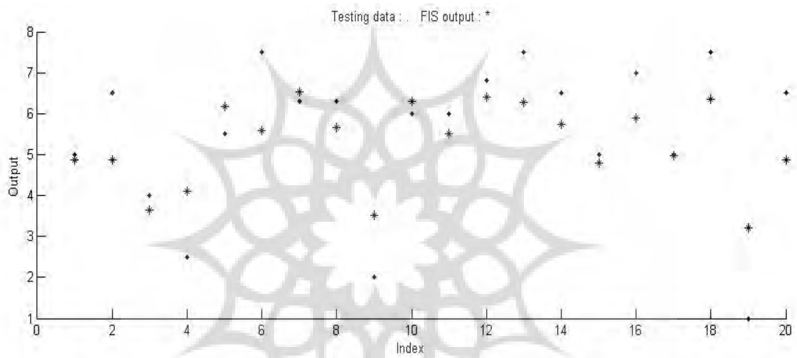

Figure 10
Comparison Between ANFIS Output and Testing Data

Statistical tests were carried out to evaluate the verification of the fuzzy inference system. In this method, experts in the field of e-learning were asked to express their views on the output of the system in terms of different, randomly generated input values. Then, the existing views were compared with the actual outputs of the designed system. Considering $\alpha = 0.05$ and using SPSS software, the P-value was calculated to be 0.071, which was greater than α. As a result, the hypothesis of equality of means is not rejected, which means that there is no significant difference between the designed ANFIS output and the knowledge of experts.

Findings and Discussion

As mentioned earlier, the resilience rate in the case study was 3.41. By changing one input and keeping the other four inputs unchanged each time and for each input, Table 4 shows the sensitivity of the model in exchange for a change in each of the inputs. The first line in Table 4 indicates the current situation and the following lines show addition of one unit to each of the factors and the amount of resilience calculated. As can be seen, the agility factor has caused a significant change in resilience such that it has transformed resilience from "medium-low" to "medium". Sensitivity analysis demonstrates that after the agility factor, technology factor and assessment and support factor should be considered as the next priorities in Iranian virtual university.

Table 4
Sensitivity Analysis

	IF	*TF*	*CF*	*AF*	*SF*	*RE*
1	*6*	*7*	*5*	*4*	*2*	*3.41*
2	*7*	*7*	*5*	*4*	*2*	*3.53*
3	*6*	*8*	*5*	*4*	*2*	*4.01*
4	*6*	*7*	*6*	*4*	*2*	*3.54*
5	*6*	*7*	*5*	*5*	*2*	*4.71*
6	*6*	*7*	*5*	*4*	*3*	*3.81*

The concept of redundancy along with flexibility, transparency, ease of access to software and hardware infrastructure, and appropriate Internet bandwidth are appropriate indicators identified for agility and they can ensure high resilience for e-learning systems. E-learning has the potential to reach the public in critical situations such as the coronavirus epidemic and this objective is realized upon achieving agility and technological development. According to Kendra and Wachtendorf (2002), a resilient system cannot be achieved if 'any of the robustness, "redundancy", resourcefulness, and rapidity is missing from an overall strategy'. The combination of redundancy and flexibility can prevent negative effects and reduce the costs of redundancy through greater transparency. Dalsgaard and Paulsen (2009) maintained that 'the potential of social networking lies in transparency and the ability to create awareness among students. It can be expected that given the new needs of today's human beings such as rapid access to computer, intelligent phones, and the Internet with appropriate speed as well as bandwidth and other existing potentials, the effort to implement and use the benefits of e-learning should be more than ever.

Conclusions

Given the importance of the resilience of any system during Coronavirus spreading, the corresponding factors (components) should be addressed so that the degree of e-learning resilience can be determined. In this regard, five significant factors were identified: individual, evaluation and support, content, technology, and agility. Because the concept of resilience is qualitative, employing powerful tools such as Adaptive Neuro-Fuzzy Inference System (ANFIS) for resilience assessment can be propounded. The purpose of using ANFIS was to optimize the parameters of equivalent FIS by applying a learning algorithm using input-output datasets. To prove the applicability of the model, the proposed methodology was applied to Iranian virtual university and the implemented system for them was of "medium-low resilience" while it should be "highly resilient" according to experts' opinions. The proposed model showed significant sensitivity to changes in agility. Therefore, agility should be considered as the first priority in achieving the desired level of resilience in the e-learning systems of virtual university in Iran. This model can be used in all educational institutions in different situations to evaluate the improvement of resilience in e-learning. Obviously, in order to implement this model in different organizations, the values of designed ANFIS and the parameters of Laplace equations should be defined specifically for every organization and the corresponding model need to be simulated by examining the involved components and relationships. For further research, Co-Active Neuro-Fuzzy Inference System (CANFIS) can be considered in investigating the multiplicity of outputs for the proposed problem.

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