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Teaching Computer Science and Computer Engineering During COVID-19 Lockdown at the Pakistani Universities*

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A study is conducted with 368 teachers teaching various undergraduate Computer Science and Computer Engineering courses in an under-developed country – Pakistan, during the COVID-19 pandemic. A teaching model is presented in this research, suggesting that the grit had played an important role in technology adoption for online teaching during the COVID-19. It is found that although the absence of technological support such as high speed Internet and consistent, robust and useful LMS, teachers were still adopting and using technologies such as Google Classroom, Zoom and WhatsApp groups for teaching the students in real-time or through recorded videos. This behavior is explained by the teacher's grit that has also motivated the adoption of online teaching related technologies. The lack of technology such as LMS does affect the user satisfaction, however, it didn't affect the usage behavior of the adoption and use of technology. The initial research model had components from non-cognitive learner characteristics, and from various popular technology usage and acceptance models such as an Information System success model, and Unified Theory of Acceptance and Use of Technology. A quantitative questionnaire survey is conducted to assess the proposed research model. The resultant research model had components only from non-cognitive learner characteristics and Unified Theory of Acceptance and Use of Technology model. The data is analyzed using SEM PLS, K-means clustering and Decision Tree classification method.

Keywords: perseverance; technology; acceptance; COVID-19; under-developed countries

1. Introduction

Most developing countries were unaware of the extent, to which COVID-19 could have affected them when China was trying to contain the effects of this virus back in January, 2020. Although, World Health Organization (WHO) has declared the virus as a global concern on 30th Jan, 2020, however, the virus didn't reach Pakistan until late February 2020. Soon after the virus reached Pakistan, the Federal Ministry of Health confirmed it and advised a total lockdown in Pakistan [1]. The schools, colleges and universities were ordered to close indefinitely on 13th March 2020. Many teachers personally known to the authors started advising the students almost immediately online using various platforms such as Zoom and Google Classroom. However, the Higher Education Commission of Pakistan (HEC) issued an official directive to the universities for preparing to teach online soon afterwards. The educational institutions couldn't shift to online teaching immediately due to various obstacles prevalent in developing countries [2]. Developing countries that are known for limited investment in education, resorted to using available technical resources to fill the demand for online teaching, using Zoom, WhatsApp or Google Classroom [4]. Although the effects and efficacy of online teaching is not well established [5] moreover the standards that might be required to fulfill for successful teaching may not be fulfilled by online teaching. However, the COVID-19 pandemic brought exceptionally new situation that warranted new standards, even if they would decrease the level of satisfaction in our academic and work life. Lack of Internet in many areas of developing countries and the lack of training in online teaching made it even more difficult to teach online. This crisis learning [6] needed improved curriculum and better command on new instructional methods [2] which is missing in developing countries. Teachers from non-computer background were the first ones to be left behind. They didn't know how to teach via online platforms and were completely clueless about how to conduct scientific experiments with chemicals, animal bodies or other such articles that require physical interaction. Moreover the assignments and teach-

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ing that required group discussion and social interaction also required new ways to get delivered. The stress of teaching through newer means was the biggest cause of psychological distress for many teachers and students [7]. Although, countries like Pakistan officially decided to instruct students online, however, due to the increased dissatisfaction of the students, there came a time when the Higher Education Commission (HEC), Pakistan ordered the universities to stop teaching online immediately [43]. However, teaching resumed shortly afterwards.

It is pertinent to inform that not many recent research studies have explored the challenges and opportunities linked with online teaching in a virtual environment or learning during pandemics [2, 8–10] probably because the world has not seen any such problem in the current century so far. Even the past virus outbreaks were mostly contained and controlled without widespread lockdowns.

It is obvious to ask if the teachers that have no consistent technological support can teach online with whatever is available? In similar situations, a teacher from developed country would have said no. It is obvious that online teaching requires very different infra-structural support as compared to what is available in normal face-to-face operations; online teaching requires student access to broadband and high speed computers, technical setups and availability of software to ensure that students still have access to good education. Most of these facilities are still a dream in under-developed countries, where most of the budget gets spent on defense related matters and a large portion of the society lives under the poverty line. These technological issues thwart teachers in under-developed countries from online teaching. Under-developed countries such as Pakistan, Nigeria, etc. face challenges that hinder online education which includes immense poverty, technical illiteracy, economic and political volatility, and pitiable technical infrastructure. However, the most damning obvious problem is the unavailability of high speed Internet connection due to the poor technical infrastructure. Unreliable Internet, upsets and deters the efforts of both the students as well as of the teachers because it causes frequent Internet disconnections. The result is that teachers can't be heard easily in online classes, questions cannot be answered straight away and takes longer response time thus overlapping the question and answers, and requires much more effort from the teachers in getting understood. Even when the Internet connection is available, its narrow signals hinders a consistent instructor-to-student communication which is a result of the constant Internet interruption which results in wasted time and ends in the frustration of both teachers and students alike. An estimate shows that there is difference of 1:5 when it comes to the frequency capacity of the broadband in under-developed and developed countries. Thus, technology is obviously not favorable for a pleasant learning environment in under-developed countries. This alone may discourage many students and instructors from participating in online education [11]. So, it is a necessary question to ask what keeps teachers motivated to keep trying to use the technology and whatever Internet is available for teaching students in times of crises such as COVID-19 in under-developed countries.

In this study it is proposed that grit plays an important role in crises situations and positively impacts user technology acceptance in terms of use of online platforms (such as Zoom, Google classroom and WhatsApp) for teaching. Researchers have always tried to answer how one individual accomplishes more than others of equal intelligence. They have found that it is a result of the interplay of cognitive ability and the factors such as vigor, creativity, emotional intelligence, self-confidence, charisma, emotional intelligence, physical attraction, and other similar attributes. Another factor that researchers have included in the above mentioned list is grit. Grit has been defined as "the combination of perseverance and passion for long-term goals" [47], and has been established to relate to the achievements of both personal and academic nature [48]. Grit involves operating persistently toward tasks, upholding determination and interest over the time, despite failure and adversity [47].

We propose an e-teaching success model that includes non-cognitive learner characteristics, i.e. grit and the models such as Information Systems success model (to cover the aspect of presence or absence of Learning Management System) and Unified Theory of Acceptance and Use of Technology model (to cover for the acceptance of technology).

2. Literature Review

Since the under-developed countries don't have the privilege of consistent Internet service and abundant knowledge of the use of ICT for teaching, therefore, when the COVID-19 pandemic spread, most faculty members were not ready for online teaching. On top of that, the universities had never invested in technologies such as a Learning Management System (LMS) and its training. The ever changing date of the resumption of face-to-face classes, forced teachers – young and old alike – to start taking classes online. Since most of the teachers had never taught online, therefore, the adop-

tion was not quick. However gradually and against all odds – such as lack of stable Internet, lack of LMS, lack of guidelines for teaching courses that required laboratory work, etc. – the teachers started using technologies such as Zoom, Google classroom and WhatsApp groups more frequently. This research proposes that even in the face of lack of facilities such as stable Internet and well-developed LMS, if the teachers adopted the technology for teaching, then it can only be attributed to their grit that influenced their behavior by the use of technology and its adoption. Therefore, the two major components of the research model presented in this research are: grit and Unified theory of acceptance and use of technology. The third component of the research model presented here is some parts of the Information System success model. It is postulated that although the situation during peak COVID-19 crises was such that there was no properly developed LMS that could have guaranteed a successful implementation of Information System, the teachers still persevere and taught. The IS success model is made part of the research model to investigate that if the IS fails and don't provide information, service and system quality thus decreasing the level of user satisfaction, would grit still enable the teachers to adopt the use of (alternative) technology so as to deliver the lectures.

Everyone from human beings to animals show different levels of grit, which is an important cognitive phenomenon that may predict important life outcomes and academic or job success (for instance, [12, 13]). Grit determines the level of effort one may put in times of challenges [14] and is taken as a psychological variable that ensures persistence for long-term success and achievement of high-level goals for a very long time [15, 16]. Grit consists of two indicators that are consistency of interest and the persistence of effort [17]. With these indicators applied consistently over a long period of time, one may expect an increase in professional competence [18–21]. How effectively a teacher teaches is also affected by his level of grit. The two grit indicators when applied consistently stimulates teaching efficacy in teachers [22–25]. Widodo [26] notes that, in the specific context of teaching, self-efficacy of teachers can be explained through ''teaching efficacy as a perspective''. Teaching efficacy ''is a teacher's perception of his or her ability to positively impact on student learning.'' This comprises of awareness of one's own expertise in teaching and the certainty that student learning can be improved through teaching [27]. Bandura [22] notes that there is a positive correlation between environment of the classroom and teaching efficacy. Teaching efficacy is also important for teacher education because it impacts how teachers behave and act in their conduct (e.g., [29, 30]). Grit which affects teacher efficacy, also predicts teacher's intentions for productively engaging in a potential task such as efficiently using a new teaching strategy [31]. Guo et al. [32] also found a positive correlation between the ability of students to learn and teaching efficacy. It is also noted that teachers with high teaching efficacy experience lesser burnout and thus they stay in the profession longer [33–35].

Whereas grit enables an individual for perseverance, there are certain other factors as well that enables the process of perseverance. In case of adoption and use of technology, those factors are: effort expectancy short EE, performance expectancy short PE, facilitating conditions short FC and social influence short SI. These are the constructs proposed by Venkatesh et al. [36] by the name of Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT explains user's intentions to use an Information System and subsequent usage behavior. The factors mentioned above directly affect the technology usage intention and behavior, whereas the facilitating conditions determine user behavior. Gender, age, experience, and voluntariness of use moderates the impact of the four key constructs on usage intention and behavior. The UTATU theory was developed through a synthetic review process of other models developed to explain information systems usage behavior.

User acceptance of use of technology can be affected by the success or failure of Information System that may be used for performing daily job needs in teaching field. For example, when the COVID-19 lockdown happened, the HEC Pakistan instructed all universities to organize online classes. Very few well-established universities of Pakistan were able to acquire a well-functioning LMS almost immediately and trained their teachers as well for using the e-resources for teaching. However, those few privileged universities either operated in private sector or catered to the needs of a fraction of the students studying in universities. Majority of the universities didn't have any LMS at all. LMS is an information system for administration, tracking, documentation, automation, reporting and delivery of educational courses. Although, universities started acquiring LMS from various sources later however the time to build, operate and maintain a robust LMS was already gone. Therefore, the teachers understood that the LMS Information Systems is failing in providing them the information, service and system quality. However, the grit in them enabled the teachers to eventually adopt the (alternative) technology and the teachers started teaching even in the absence of a working IS (i.e. LMS) and a consistent Internet by exploiting the recording capabilities and live meeting capabilities

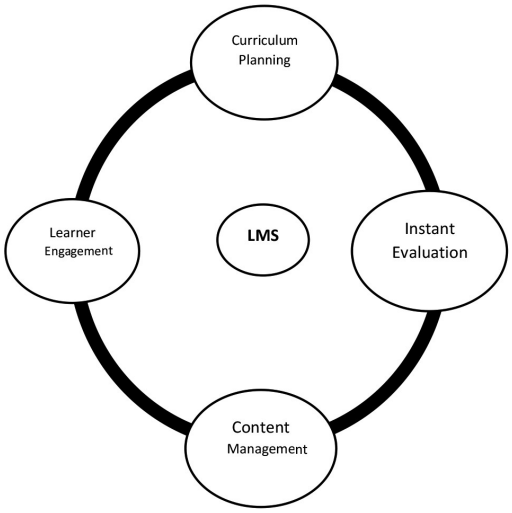

Fig. 1. Learning Management System Features.

of the tools such as Zoom, Google Classroom and WhatsApp. The third component of the proposed research model in this paper is the IS success model [40]. This component was used to capture the views of the teachers when the IS i.e. LMS was either completely unavailable or failed to provide them the necessary support. The questions were asked in praise of the LMS IS and a negative answer to such questions pointed out the dissatisfaction with the LMS IS. The teachers were often using the LMS mostly to upload teaching material and exam results only [37]. An effective LMS could have eased the nerves of first time online teachers. However teachers still continued to teach online when the LMS failed to deliver its promised benefits. The common features of any education LMS (Fig. 1) are "content management, assessment and testing, curriculum planning, reports generation, communication and collaboration, and classroom announcements".

3. Research Model

In the following section, a model for research is proposed to study the impact of various factors on user acceptance of technology for teaching during COVID-19 in under-developed countries, even when there is no robust and proven LMS available. The proposed model contains three main components: grit (which is a non-cognitive ability) which comprises of consistency of interest and perseverance effort, lack of robust and consistent LMS technology (system quality, service quality, information quality), and Unified Theory of Acceptance and Use of Technology (UTAUT). It is established from Aparicio et al. [38] that grit has played a critical role in e-learning success. Online teaching is new for developing countries. Therefore, if teachers were still teaching in developing countries using technology such as Zoom and Google Classroom, in the absence of the LMS, proper Internet, enough knowledge of computers and software, then the success of online teaching should be attributed to the cognitive skill of grit. In this study, a teacher technology acceptance and e-teaching model is proposed which proposes that grit has a positive impact on technology acceptance and use in the form of applications such as Zoom, Google Classroom, and WhatsApp group etc. to the point of satisfaction even in the absence of proper Leaning Management System (LMS).

Grit enabled the teachers to accept the technology usage in their teaching even in the absence of robust and dependable information systems such as LMS. Dependability or otherwise of an LMS can be gauged from the quality of information, system and service that it provides. Therefore, if an LMS does not provide these, then user dissatisfaction should be expected. Since the research is set in the context of those countries that were not ready for online teaching and didn't have any properly working LMS, therefore, to capture the effects of absence of LMS, the following constructs are included in the research model that are coming from IS success model: information quality, system quality, service quality. The research model is presented in Fig. 2. The constructs of the model are explained in the following references [36, 40]. The following research hypothesizes the below given hypotheses:

H1a. Grit construct is composed of: perseverance effort.
H1b. Grit construct is composed of: consistency of interest.
H2. Grit affects positively the use and acceptance of Technology/e-learning systems thus instigating user satisfaction.
H3. User Satisfaction influences the Use Behavior positively.
H4. Information quality stimulates user satisfaction positively.
H5. System quality stimulates user satisfaction positively.
H6. Service quality stimulates user perceived satisfaction positively.
H7. Performance Expectancy stimulates the Behavioral Intentions positively.
H8. Effort Expectancy stimulates the Behavioral Intentions positively.
H9. Social Influence stimulates the Behavioral Intentions positively.
H10. Behavioral Intentions stimulates the Use Behavior positively.
H11. Facilitating Conditions stimulates the User Satisfaction positively.

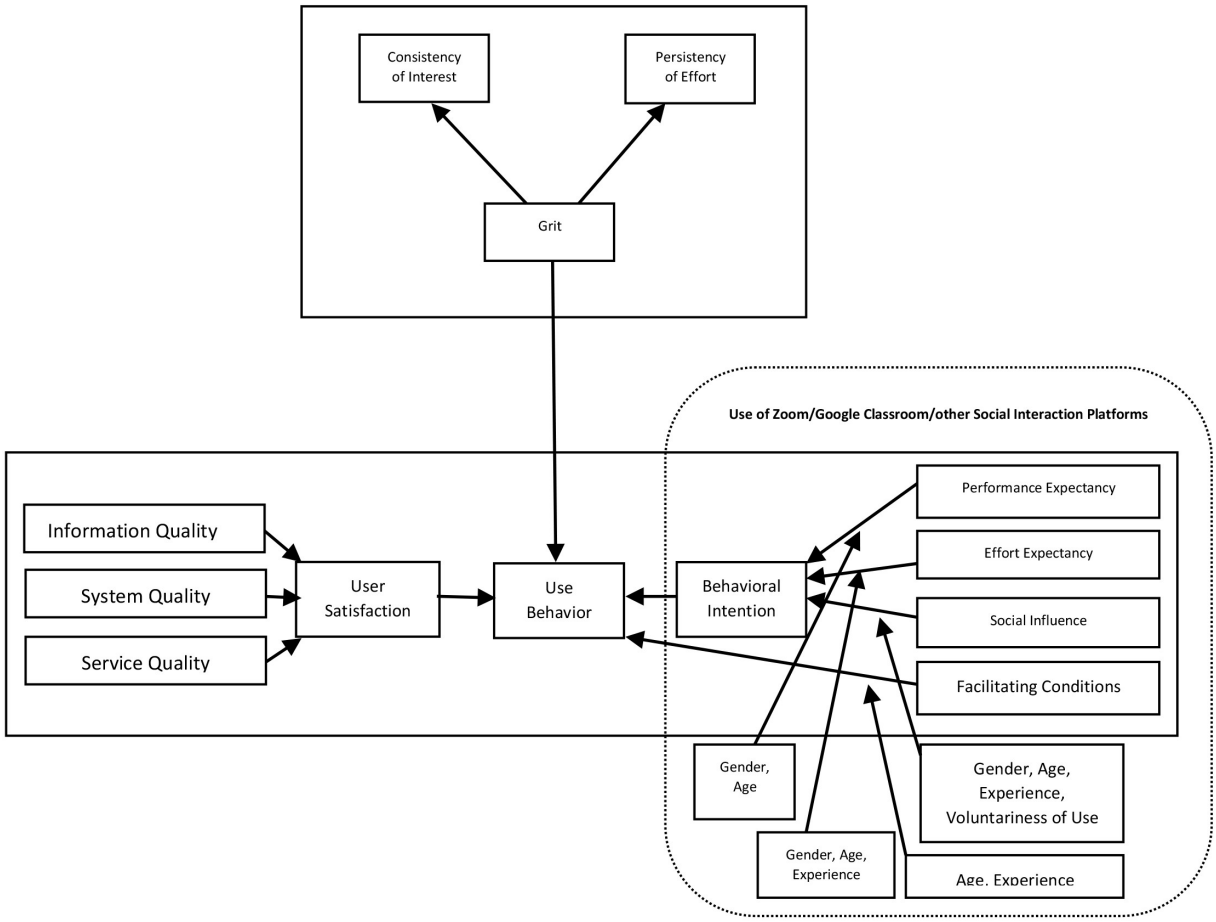

Fig. 2. Research Model.

4. Data Collection

A quantitative survey is used to assess the proposed theoretical idea; the survey was directed at the Computer Science and Computer Engineering university teachers from an underdeveloped country – Pakistan. The questionnaire was composed of the questions formed around the research indicators. The questions were answered on a Likert-type 7 point scale which consisted of options (1: Strongly disagree, 2: Mostly disagree, 3: Least disagree, 4: Slightly agree, 5: Moderately agree, 6: Agree, 7: Strongly agree). It also included questions on the following characteristics of respondents: age, gender, which e-teaching/learning platform they use, number of years of teaching experience and voluntariness of the use of technology. Questionnaires were distributed via email to several universities with and without an LMS and located in Karachi. The data were collected between mid of June to early August 2020 – the continued lockdown period. A total of 500 teachers responded to the survey, out of which, 368 were considered valid. Table 1 shows the sample characteristics. Table 2 shows the construct indicators.

Table 1. Sample characteristics and representativeness Characteristics

Characteristics	**Sample**
Gender	150
Male	218
Female	368
Total	
Instructional Level	
Undergraduate	0
College Degree (2 years)	0
College Degree (4 years)	12
Masters' Degree	18
PhD Degree	338
Total	368
Social Interaction Classrooms	
Zoom	279
Google Classroom	89
WhatsApp groups/others	0
Platforms	
Moodle or non-Moodle University-developed LMS	85

Table 2. Proposed Model Constructs and Related Indicators

Construct	Indicator
Perseverance Effort	I finish whatever I begin.
	I am not discouraged by the setbacks.
	I work hard.
Consistency of Interest	I often change my own set goals. (R)
	I loss interest in a certain idea that I have been obsessed with. (R)
	I loss focus of projects that take more than a few months to complete. (R)
Information Quality	The information provided by LMS is useful.
	The information provided by LMS is understandable.
	The information provided by LMS is interesting.
	The information provided by LMS is reliable.
System quality	The LMS is easy to navigate.
	The LMS allows me to find easily the information I am looking for.
	The LMS is well structured.
	The LMS is easy to use.
Service Quality	The service personnel are always willing to help whenever I need support with the LMS.
	The service personnel provide personal attention when I experience problems with the LMS.
	The service personnel provide services related to the LMS at a pre-arranged time.
	The service personnel had sufficient knowledge to answer my questions about the LMS.
Performance expectancy	The use of technology is useful in my job.
	I accomplish my tasks more quickly by using the technology.
	Technological support increases my productivity.
	If I use the technology, I might get a pay raise.
Effort expectancy	My interaction with the technological systems is clear and comprehensible.
	I will get used to using technology quickly.
	I am not finding it hard to use the technological system.
	Getting training in using the technology is easy for me.
Attitude toward using technology	I am surprised by the benefits of using the technological system usage in teaching.
	I love my work even more, after I started using technology.
	Working with the technological system is fun.
	I like working with the technological system.
Social influence	People who inspire me encourage me to use the technological system.
	People who are important to me think that I should use the system.
	Senior management of my university encourages me use the technological system.
	The university has supported the use of the technological system.
Facilitating conditions	I have the right infrastructural resources necessary to use the technological system.
	I have the knowledge necessary to use the technological system.
	The system is not compatible with other systems I use.
	There are people that assist with technological system difficulties.

5. Analysis And Results

The goal of this research is to explore the relationship between technology acceptance and user, and Grit under the absence of a robust Learning Management Information System (LMS) during a crises situation i.e. COVID-19. Construct reliability, indicator reliability, convergent validity, and discriminant validity were used for the measurement of the model. Composite reliability test for each construct is conducted in order to test construct reliability, which was found to be above 0.837 for all constructs. Cronbach's alpha values were found between 0.70 and 0.90 for all constructs, which suggests the reliability of each construct. All item loadings were above 0.70, indicating that all indicators were reliable. Construct's average variance extracted (AVE) was calculated and was found to be greater than 0.5.

To assess the validity of the model and its constructs, structural equation modeling (SEM) with the method of partial least squares (PLS) [39] is employed (see Table 3). The results have shown that grit is a significant factor for explaining perseverance effort ($\hat{\beta} = 0.852$, $p < 0.01$) and consistency of interest ($\hat{\beta} = 0.876$, $p < 0.01$). Information quality ($\hat{\beta} = 0.756$, $p < 0.01$), system quality ($\hat{\beta} = 0.769$, $p < 0.01$) and service quality ($\hat{\beta} = 0.806$, $p < 0.01$)

Table 3. Results of hypotheses tests

Hypothesis	Independent variable	Dependent variable	Finding Models	Conclusion
H1. Grit construct comprises of: perseverance effort and consistency of interest.	Grit	Perseverance Effort	Statistically positive significant ($\hat{\beta} = 0.852$ $p < 0.01$)	Supported
H1. Grit construct comprises of: perseverance effort and consistency of interest.	Grit	Consistency of Interest	Statistically positive significant ($\hat{\beta} = 0.876$ $p < 0.01$)	Supported
H2. Grit positively influences the use and acceptance of Technology/e-learning systems thus instigating user satisfaction.	Grit	Use Behavior	Statistically positive significant ($\hat{\beta} = 0.805$ $p < 0.01$)	Supported
H3. User Satisfaction stimulates the Use Behavior positively.	User Satisfaction	Use Behavior	Statistically positive significant ($\hat{\beta} = 0.078$ $p < 0.01$)	Supported with medium effects
H4. Information quality stimulates user satisfaction positively.	Information Quality	User Satisfaction	Statistically positive significant ($\hat{\beta} = 0.756$ $p < 0.01$)	Supported
H5. System quality stimulates user satisfaction positively.	System Quality	User Satisfaction	Statistically positive significant ($\hat{\beta} = 0.769$ $p < 0.01$)	Supported
H6. Service quality influences user perceived satisfaction positively.	Service Quality	User Satisfaction	Statistically positive significant ($\hat{\beta} = 0.806$ $p < 0.01$)	Supported
H7. Performance Expectancy stimulates the Behavioral Intentions positively.	Performance Expectancy	Behavioral Intention	Statistically positive significant ($\hat{\beta} = 0.753$ $p < 0.01$)	Supported
H8. Effort Expectancy stimulates the Behavioral Intentions positively.	Effort Expectancy	Behavioral Intention	Statistically positive significant ($\hat{\beta} = 0.760$ $p < 0.01$)	Supported
H9. Social Influence stimulates the Behavioral Intentions positively.	Social Influence	Behavioral Intention	Statistically positive significant ($\hat{\beta} = 0.820$ $p < 0.01$)	Supported
H10. Behavioral Intentions stimulates the Use Behavior positively.	Behavioral Intention	Use Behavior	Statistically positive significant ($\hat{\beta} = 0.796$ $p < 0.01$)	Supported
H11. Facilitating Conditions stimulates the User Satisfaction positively.	Facilitating Condition Use Behavior		Statistically positive significant ($\hat{\beta} = 0.732$ $p < 0.01$)	Supported

statistically significantly explained the user satisfaction. However, user satisfaction is found minimally statistically significant in explaining the use behavior ($\hat{\beta} = 0.078$, $p < 0.01$). Grit is found statistically significant in explaining the use behavior ($\hat{\beta} = 0.805$, $p < 0.01$). Performance expectancy ($\hat{\beta} = 0.753$, $p < 0.01$), effort expectancy ($\hat{\beta} = 0.760$, $p < 0.01$), and social influence ($\hat{\beta} = 0.820$, $p < 0.01$) were found statistically significant in explaining the behavioral intention similarly facilitating conditions is found statistically significant in explaining the use behavior ($\hat{\beta} = 0.856$, $p < 0.01$). Behavioral intention is also found statistically significant in explaining the use behavior ($\hat{\beta} = 0.732$, $p < 0.01$). Thus all hypotheses except H3 are found as statistically significant, indicating that the structural model is valid.

Based on the current findings it is revealed that an imperfect LMS has prone the teachers to find refuge in their ability to persevere and learn to adopt the technology instead of waiting for the LMS to improve. Therefore, the initial research model can be distilled to its new form that is presented in Fig. 3. The model now narrates that, teachers in underdeveloped countries kept teaching during the COVID-19 pandemic relying on their grit (which is a result of consistency of interest and perseverance effort) and their ability to adopt the technology (such as WhatsApp, Zoom and Google classroom). The LMS that was made available to the teachers failed to fulfill its intended requirements thus discouraging the teachers to ignore it all together or to stop relying on it apart from updating information on it only casually. However it is found that where available, a robust and consistent LMS does affected the user satisfaction and behavior positively.

K-means segmentation is also applied to find suitable clusters. K-means is one of the most famous techniques for segmenting a dataset into suitable number of clusters. There are various approaches for k-mean clustering. The algorithm

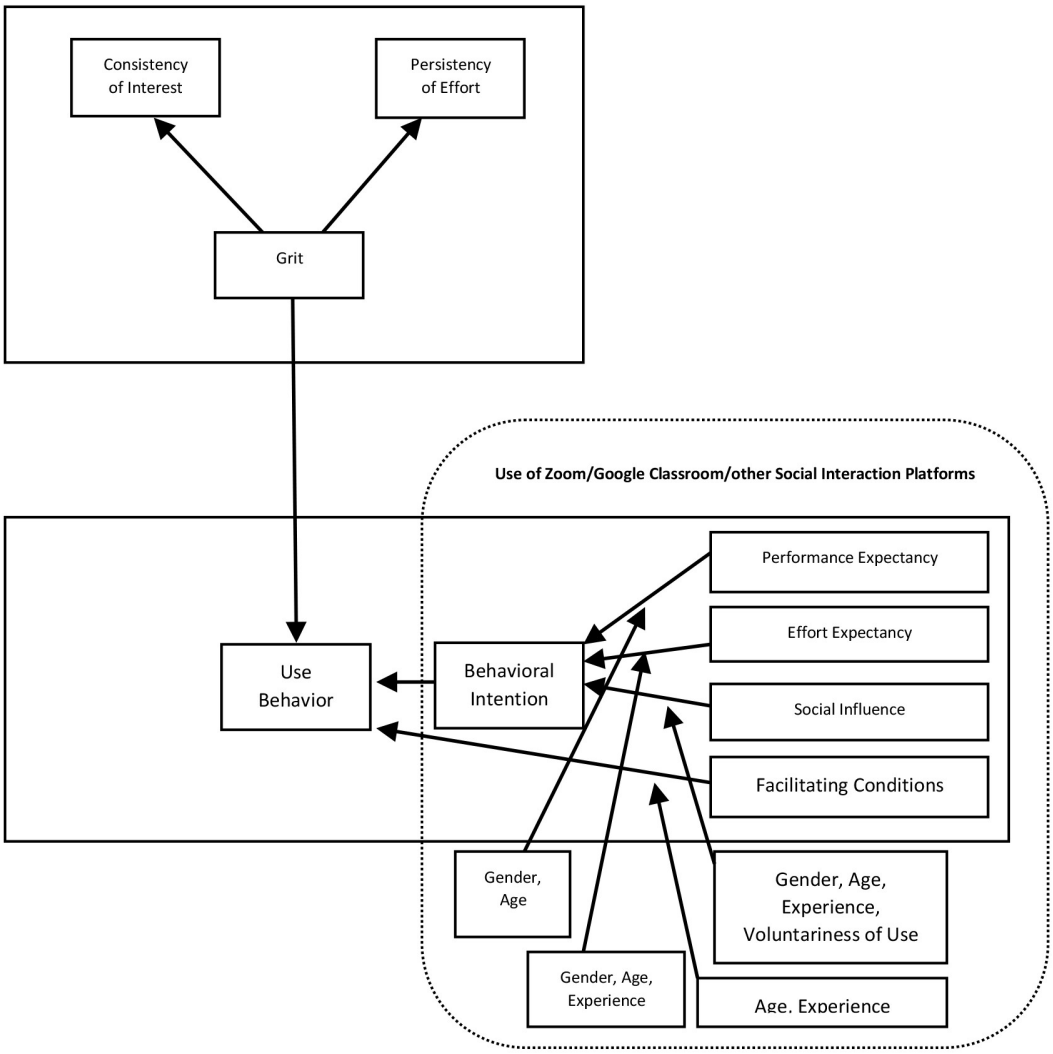

Fig. 3. Distilled Research Model.

work by splitting the data into k clusters initially. For each of the k clusters, the centroid (mean or median or mode, depending on the type of K-mean algorithm) is computed. Intra cluster and inter cluster variations are computed. Each point is allocated to the cluster that has the minimal proximity from one of the k centroids. The process of re-assignment of data points into their clusters is performed iteratively until the objective function is met. The objective function in K-means is to minimize the intra-cluster variations (sum of squares for each cluster). The algorithm produces a cluster label for each data point. In probabilistic clustering, in addition it also produces the probability of belongingness of a data point with the jth cluster, j = 1,2, . . . , k. For the given dataset, we started with k = 2 clusters and kept increasing k until found that k = 3 is the optimal number for this dataset. There are 40 variables in the questionnaire. The mean and standard deviations for some of the significant variables are presented in the Table 4. The non-parametric Kruskal-Wallis test is also applied to compare the three cluster results for only those variables that were found significantly different among the three clusters. View Table 4 for K-means segmentation as well. Age is significantly different among three clusters. Cluster-1 staff has mean age 26.5 years, which is lower than those in cluster-2 and cluster-3 with mean age 39.4 and 41.2 years. Age is useful discriminator among the three segments. Experience is another useful classifier for these three clusters. Cluster-1 consists of staff with mean = 2.3 years of experience whist for the cluster 2 and 3, mean experience are 8.6 and 8.9 years. In sum, age and experience classified staff as cluster-1 (young/career starters), cluster-2 (middle aged/ middle career) and cluster-3 (senior aged/ senior career).

The data collection through questionnaire is a representation of a large class of faculty staff in Pakistan. Therefore, to understand interests, productivity, alignment with LSM and technological

Table 4. K-means of Identified Clusters of Some Variables

Variables	P-Value	Cluster-1 (n = 137)		Cluster-2 (n = 106)		Cluster-3 (n = 125)	
		Mean	SD	Mean	SD	Mean	SD
Age	0.000	26.5	2.6	41.2	4.9	39.4	4.9
Experience	0.000	2.3	1.7	8.9	1.6	8.6	1.7
I work hard.	0.023	6.1	0.8	6.2	0.8	5.9	0.8
I often change my own set goals. (R)	0.004	1.9	0.8	2.2	0.8	1.8	0.8
I loss interest in a certain idea that I have been obsessed with. (R)	0.000	2.1	0.8	1.7	0.8	2.3	0.7
The information provided by LMS is useful.	0.000	2.0	0.8	1.7	0.7	2.4	0.8
The information provided by LMS is understandable.	0.029	2.1	0.8	2.1	0.9	1.8	0.8
The information provided by LMS is interesting.	0.038	2.1	0.8	2.2	0.8	1.9	0.8
The information provided by LMS is reliable.	0.000	2.1	0.8	2.2	0.8	1.8	0.8
The LMS allows me to find easily the information I am looking for.	0.004	2.0	0.8	2.2	0.8	1.8	0.7
The service personnel are always willing to help whenever I need support with the LMS.	0.040	1.9	0.8	2.2	0.8	1.9	0.8
The service personnel provide personal attention when I experience problems with the LMS.	0.000	2.0	0.8	1.8	0.8	2.3	0.8
The service personnel provide services related to the LMS at a pre-arranged time.	0.000	2.0	0.8	1.7	0.8	2.1	0.8
Technological support increases my productivity.	0.004	5.9	0.8	6.2	0.8	5.9	0.8
If I use the technology, I might get a pay raise.	0.000	5.9	0.8	5.9	0.9	6.3	0.8
My interaction with the technological systems is clear and comprehensible.	0.004	6.0	0.8	6.2	0.8	5.9	0.8
I will get used to using technology quickly.	0.028	6.1	0.8	6.2	0.8	5.9	0.8
I am not finding it hard to use the technological system.	0.009	6.1	0.8	5.8	0.8	6.1	0.8
Working with the technological system is fun.	0.000	6.0	0.8	6.3	0.8	5.8	0.8
People who inspire me encourage me to use the technological system.	0.006	5.0	0.8	4.9	0.8	5.2	0.8
The university has supported the use of the technological system.	0.032	5.0	0.8	5.0	0.8	4.8	0.8
I have the right infrastructural resources necessary to use the technological system.	0.044	5.6	1.1	5.3	1.1	5.6	1.1
I have the knowledge necessary to use the technological system.	0.000	5.8	1.0	5.4	1.1	5.1	1.1
The system is not compatible with other systems I use.	0.001	5.4	1.1	5.8	1.1	5.2	1.1

absorptions, the attitudes could be modeled as a prediction model. A prediction model based on the attributes of the data is converted in the form a machine learning predictive model, i.e. decision tree classification model. The model considers the cluster number as dependent variable whereas the 26 significant variables are used as predictors. The model performance is assessed with the classification matrix as presented in the following. The rows represent the actual /observed cluster whereas the columns represent the predicted cluster. Numbers in the diagonal presents the correct classification (when observed cluster = predicted cluster) whereas numbers in the off diagonal are miss-classifications. The correct classification for young, middle and senior faculty are 98.5%, 85.6% and 92.5%. The middle faculty is less accurate than others are, as their approaches include testing and trying different approaches to get the best of them. Overall accuracy of the model is 92.4%. The modeling is performed with k-fold techniques to check for model validation in the absence of external cohort. Using the following graphical tree model; it is straight forward to classify any new faculty member as one of the three clusters as shown in Table 5.

6. Discussion

Majority of the hypotheses were found statistically significant. It is found that grit is form from

Table 5. Classification based on Decision Tree Classification

	Predicted			
Observed	**Young**	**Senior**	**Middle**	**Percent correct**
Young faculty	135	1	1	98.5%
Senior faculty	0	98	8	92.5%
Middle faculty	3	15	107	85.6%
Overall Percentage	37.5%	31.0%	31.5%	92.4%

Growing Method: EXHAUSTIVE CHAID; Dependent Variable: Cluster.

two factors that are perseverance effort and consistency of interest – a result which is substantiated by other researchers as well [38]. Similarly, much like other researches [40, 41], it is found that user satisfaction is influenced by information quality, system quality and service quality. However, it is also found that user satisfaction does not affect use behavior. It is found from the questionnaire analysis that, when the information, system and service quality is not satisfactory even then, the teachers were using the platforms such as Google Classroom, Zoom and WhatsApp for lecturing the students. the better quality of information, system and service did encourage the teachers to use these above mentioned platform more productively, however, the absence of LMS or its ineffectiveness didn't discourage the teacher. This indicates that the grit of the teachers (H2) positively encouraged the teachers to keep teaching. The behavioral intention is influenced by effort expectancy, performance expectancy and social influence. Soon after the COVID-19 patients started emerging in the country, several Pakistani teachers started teaching students online. They shared their experience with others, which automatically induced an excitement to teach online in other teachers. Teachers were also influenced socially by their peers to teach online. Soon, teaching online became a trend; this also encouraged the Higher Education Commission of Pakistan to officially instruct the universities to adopt online teaching. However, since there were no standards available for teaching those students online that had not been exposed to such means of instruction, moreover, since the teachers too were not aware of how to conduct classes online or what to do with the experiments that require physical presence and use of expensive and industrial equipment, chemicals and resources, therefore, there were no set performance expectancy and effort expectancy standards available. A time did come during the online session, when the Higher Education Commission of Pakistan instructed the universities to immediately stop teaching online because of severe complains about poor performance and efforts of the teachers in teaching online [43].

Whereas, this incident shows that the teaching online was not easy for the teachers, however this also shows that the teachers were still making an effort in teaching online even those subjects that required physical usage of expensive equipment (such as Chemistry, Zoology, medicines, etc.) This continued interest in teaching online is attributed to the grit of the teachers in the model proposed in this research. Behavioral intention is also motivated by the facilitating conditions. Teachers were facilitated to teach online by the tech giants themselves such as Zoom, Google Classroom and WhatsApp. The ability to record a lecture and share it with the students online made online learning easy even for those students that were living in far flung areas where the Internet connection was almost non-existent. Zoom even lifted the 40 minute limit for meetings at one point during the COVID-19 crises [42]. Various measures by the technology platforms encouraged the use behavior of the teachers during COVID-19 crises and encouraged teaching using these platforms. Gender, age and experience of teaching also moderated the relationship between behavioral intention and its influencing factors such as performance expectancy, effort expectancy, social influence and facilitating condition.

Whereas the teachers were motivated to adopt technology for teaching online, the absence of a well-established Learning Management System was expected to hamper all such efforts. The developed countries shifted to online teaching rather comfortably because of their ability to either acquire a well-established LMS almost immediately or get it developed instantly. Moreover, most teachers in the developed countries are tech savvy and understand how to use the technology for their benefit. However, the developing countries didn't have the luxury of well-established LMS before the COVID-19 crises began. And when the COVID-19 crises had started, the universities were told to build, train and use LMS almost immediately. A government funded university Virtual University of Pakistan, had a well-developed LMS that it offered to other universities. However, most universities didn't opt it in favor of Moodle. A slow progress towards developing an LMS as per the need of each university further encouraged the teachers not to wait

for it. Whereas the data shows that information quality, service quality and system quality motivated teachers' satisfaction, however, data collected in this research also showed that in under-developed countries such as Pakistan, lack of information, system and service quality didn't discourage the teachers from keep using technology for teaching. This is perhaps because teachers were not aware of the benefits of LMS nor had they used it in the past, therefore they never assumed it to be important enabler for technology adoption in teaching.

Conclusion can be drawn that during the COVID-19 crises, teachers from the under-developed countries adopted technology for teaching various courses even in the face of various difficulties such unavailability of high speed Internet or training in use of technology for teaching. This decision to adopt technology for teaching is attributed to grit of the teachers. Moreover, the unavailability of a comprehensive LMS didn't discourage the technology adoption, although, a comprehensive LMS is found important for user satisfaction thus influencing the use behavior. A comprehensive LMS would increase the user satisfaction and thus positively influencing the use behavior however an incomprehensive LMS didn't affected the use behavior negatively.

Data also shows that there are three clusters that can be found among teachers that had taught in the absence of a robust and proficient LMS, through their grit and the ability to adopt the technology. Those three groups are identified on the basis of the age of the teacher and his experience of teaching (Tables 4 and 5). Data has shown that the young faculty members and the senior faculty members were making more efforts to teach using every possible means, such as Zoom, and other technologies and they were trying to interact with the LMS as well hoping to get it to work for them somehow. However, the middle career teachers were not as adamant and as keenly hard working as other groups. It can be researched separately that why and if middle career teachers are not as tenacious as their younger and senior counterparts.

7. Future Work

One may ask if the teacher's devotion to teaching can be maintained in the long-term. Since the COVID-19 situation is still evolving and the people will have changed their work routine all over the world, would the current teaching practice will become a routine and most effective approach? The answer lies in Bridges' [49] model of psychological transitions which have the following three stages: Endings and letting go; the neutral zone and New beginnings. The neutral zone is the point at which the old reality and ways of working have gone, but new ways have not yet fully formed. The COVID-19 situation is the "neutral zone"; At this point everyone including the teachers has adopted new roles and has accepted the new responsibilities. Imparting education has transformed following the COVID-19, for many Higher Education Institutions; it is unlikely that the way the HEIs used to operate shall return any time soon. The recent rushing to embrace technology for online teaching means that the foundation has been laid to acclimatize resources and content for online delivery and it is therefore it is highly likely that the situation will remain this way for a long time. However, it is necessary to study that how long any alterations caused by the COVID-19 are likely to be persistent. Readers are encouraged to investigate in this direction as well [50].

It must also be noted that the focus of this research has been the teachers and their commitment to teaching during a crises like situation, such as the COVID-19. It would be interesting to study the grit of students as well in the backdrop of the COVID-19. It has been established in literature that grit was beneficial to learners and was found related with academic achievement, educational performance, academic adjustment, and graduation rates [45–47]. The research on the effects of COVID-19 on engineering education is on-going as can be seen from the following references [51–55]; this shows that the engineering education will not be taught to the students in the same way as it was done before the COVID-19, once the lockdown will be lifted forever.

8. Conclusion

This current research has proposed a model that explains how and why teachers from the under-developed countries such as Pakistan, adopted technologies for teaching students amid the lack of most necessary facilities. The research has shown that the adoption of technology can be attributed to the grit of the teachers that had motivated them to adopt technologies such as Zoom, Google Classroom, WhatsApp groups etc. for teaching.

This research has also shown that whereas quality information, system and service could positively influence the adoption of technology, however in case of under-developed countries such as Pakistan where there was no stable, authentic and robust Learning Management System and the country lacked high speed Internet facility, teachers were not de-motivated by the lack of these facilities. They kept persevering and kept a continued interest in technology adoption for teaching.

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