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A neural network approach for assessing quality in technical education: an empirical study

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Abstract: The diverse nature of requirements of stakeholders in a Technical Education System (TES) makes it extremely difficult to decide on what constitutes quality. Hence, identification of common minimum quality items suitable to all stakeholders will help to design the system and thereby improve customer satisfaction. To address this issue, a measuring instrument known as EduQUAL is developed and an integrative approach using neural networks for evaluating service quality is proposed. The dimensionality of EduQUAL is validated by factor analysis followed by varimax rotation. Four neural network models based on back-propagation algorithm are employed to predict quality in education for different stakeholders. This study demonstrated that the P-E gap model is found to be the best model for all the stakeholders. Sensitivity analysis of the best model for each stakeholder was carried out to appraise the robustness of the model. Finally, areas of improvement were suggested to the administrators of the institutions.

Keywords: service quality; expectations; perceptions; customer; EduQUAL; sensitivity analysis.

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1 Introduction

Service quality may be viewed from three perspectives: the performance of the product, behaviour of service provider's personnel and attitude of customers. The diverse viewpoint of service quality and its intangibility characteristic leads one to express service quality as the difference between customer expectations (before delivery of service) and perceptions (after delivery of service) (Berry *et al*., 1985). A positive difference (or gap) implies that expectations are greater than performance, *i.e*., perceived quality is less than satisfactory, leading to occurrence of dissatisfaction of the customer (Parasuraman *et al*., 1985). In an organisational context, any effective quality control programme focuses on the identification of areas having large gaps so that efforts can be made to minimise the gap to obtain a competitive edge over competitors.

Among all service sectors, the education sector, particularly the Technical Education System (TES), has direct bearing on society for society's growth and socio-economic development. One of the key skills required of an engineer is the ability to produce systems that satisfy users' requirements by correct selection, configuration, integration, operation and control of proprietary building blocks. In India, the fact was realised quite early and the impulse to create centres of technical training came long ago. Today, many engineering colleges and technical universities with different courses in undergraduate, postgraduate and research levels are in existence and compete with each other as well as with the foreign institutes for imparting education. The All India Council of Technical Education registers 1346 engineering colleges in various parts of the country with an annual intake capacity of 439 689 in different branches of engineering and technology. The limited number of state-funded institutions and diminishing funding in higher education from the government caused the mushrooming of private institutions in India. Therefore, the students have a wide range of options to choose from which the institution to pursue their interests. As the students bear the complete expenditure of education, they deserve the best education. Therefore, quality has become a competitive weapon for the institutions to serve and attract their primary customers (students).

To this end, the development of a quality measurement instrument for the educational set-up and a methodology for the assessment of quality is of prime importance for providing guidelines to the administrators of the institutions. The quality indicators must satisfy all the stakeholders involved in the system. In an educational set-up, multiple stakeholders, *viz*. students, alumni, parents, recruiters, faculties, supporting staff, government, society and administrators, interact with the system in different ways and have diverse expectations. Therefore, the service items are likely to differ amongst

stakeholders. The administrators of the educational set-up find it very difficult to fix the norms that would suit all the stakeholders. This study attempts to develop a uniform construct (minimum number of items) of service that meets the service requirement of important stakeholders. Specifically, the study tries to identify the areas of improvement that need to be focused on by the management of the organisation to improve quality of education. To address these issues, a survey instrument known as EduQUAL, specifically proposed for the education sector, is used to measure the satisfaction level of different stakeholders. Evaluation of service quality is attained by implementing a neural network approach (Hoefer and Gould, 2000; Tam and Kiang, 1992; Nordmann and Luxhoj, 2000). Such an approach may enable one to address three fundamental issues: first, the consideration of applying a neural network adequately for modelling of customer evaluation of service quality in education; second, since the neural network is considered to be a 'brain metaphor' of information processing, it may be possible to get some insight into the issues related to how service quality is being currently measured and evaluated; third, the study demonstrates effective utilisation of neural network models by the service providers for identification and improvement of the quality of service.

2 A brief literature review

Education in general and higher education in particular represents too-process-oriented, intangible and multiple-stakeholder situations. Most of the performance measurement systems of higher educational institutions do not reflect the full range of interested stakeholders and are not closely linked to the strategic management. Therefore, Cullen *et al*. (2003) propose the use of a balanced scorecard approach in order to reinforce the importance of managing rather than just monitoring performance. Garretson (2004) confirms the importance of the expectation of key stakeholders in the educational process while exploring the meaning of quality through students' evaluation of an MBA programme using a combination of qualitative and quantitative approaches. Temponi (2005) analyses the main elements of continuous improvement in higher education that address the concerns of academia's stakeholders during the process of its implementation. Lomas (2004) emphasises the selection of a particular quality management model such as European Forum for Quality Management (EFQM) and Total Quality Management (TQM) for promoting continuous improvement of quality in education. In addition, a few studies highlight the method of pedagogy and selection of institutes of higher learning (Felix, 2001; Poonikom *et al*., 2004).

SERVQUAL (and its modified versions), a multiple-item survey instrument that supports qualitative analysis with quantitative information, is still popular among researchers as far as assessment of service quality is concerned, and has been applied to different service sectors (Parasuraman *et al*., 1985; 1988; 1991; Parasuraman *et al*., 1994a; Parasuraman *et al*., 1994b). The instrument uses five core criteria (dimensions) consisting of 22 pairs of components evaluated on a 7-point Likert-type scale under which customers decide in evaluating the service quality. The first 22 items are designed to measure customer's pre-purchase expectations for a particular service and the other 22 items are provided to measure the perceived level (perceptions) after delivery of service. Service quality is the 'gap' between expectations of a customer from the service provider and the perception of the service experienced by the customer (popularly known as the

P-E gap). The SERVQUAL-based gap model has been effectively used for assessing quality practices to provide guidelines for improvements (Chua, 2004; Joseph *et al*., 2005; Shanahan and Gerber, 2004). However, poor reliability and interfactor correlations of SERVQUAL led to the proposal to use SERVPERF (perception-only model) and HEdPERF (Higher Education PERFormance) for efficient measurement of service quality (Cronin and Taylor, 1994; Abdullah, 2005).

In addition to the popular P-E gap model, two more models – Expectations minus Perceptions (or E-P gap model) and Expectations and Perceptions (E&P) model – have been proposed to take care of preconceived expectations of customers before the service has been delivered (Behara *et al.*, 2002). It is observed that the E-P model performs best compared to other models when tested using neural networks in an auto-dealership network. The study by Behara *et al.* also demonstrates that neural networks based on back-propagation algorithm can be effectively used for modelling and evaluating qualitative and intangible aspects of service quality. Hoefer and Gould (2000) used the neural approach to predict students' academic performance in a business programme, whereas Nordmann and Luxhoj (2000) applied it to forecasting of service problems in aircraft structural component grouping. Tam and Kiang (1992) applied a neural approach to predicting failures in the banking sector.

3 Stakeholders in the technical education system

Quality planning and improvement in any organisation necessitates identification of its customers and realising their requirements. In education, quality is all about systems that lead to good academic culture, excellent academic results, progressive and adaptive management, clean administration and prominent profile of outgoing students. It involves the expectations and perceptions of a large number of interested parties such as students, faculty, supporting staff, administrators, parents of the students, alumni, domestic and offshore partners, career advisors, government, industry (recruiters) and society (Natarajan, 2002). They interact with the system in different ways and their objectives may be different. Therefore, the implementation of any quality improvement programmes necessitates the identification of various potential customers in an educational set-up and determination of their specific needs to maintain customer-oriented service (Lembcke, 1994; Spanbauer, 1995).

Kanji *et al*. (1999) classify the customers of the higher education system into primary and secondary groups on the basis of their locations (internal or external) and frequency of interactions with the institution. Sirvanci (1996) indicates that the students are generally assumed to be the principal customers and take on different roles within the institution. They are the product of the process, the internal customers for many campus facilities, the labourers of the learning process and the internal customer of the delivery of the course material. Sometimes the customers are classified into three groups: input customers, transformation customers and output customers. Students and parents are included in input customers, the faculty is the transformation customer and the corporations and society are the output customers (Madu *et al*., 1994). Nevertheless, it is generally accepted that students are the primary customers and the other potential customers such as alumni, parents, employers, employees, government, industry and society may be considered secondary customers (Owlia and Aspinwall, 1996).

The Malcom Balridge National Quality Award Education Pilot Criteria, which were adapted from the Balridge Award Criteria for Business, recommends avoiding use of the term 'customer'. Rather, it recommends the use of students and stakeholders in place of 'customer' for an education system.

Among all the stakeholders, the students of an institute may be considered the most important stakeholders, as they are the significant customers of a TES compared to other stakeholders. Students are the prime users of the TES in order to prove themselves as competent technical professionals. Their satisfaction is an important determining factor to ensure the quality of education being imparted. The main objective of a TES is the retention of students in the institute through the development of methodologies for improving the quality of education/research and establishment of a brand of their own. The objective can be achieved by focusing on key areas that need improvement through measurement of the expectation and perception levels of the students. Similarly, alumni stay connected with their alma mater, classmates, friends and faculties. The institute fosters lifelong learning through its various programmes to help alumni to be successful in their professional pursuits. They not only take interest but also render support, including financial, to upgrade the quality of education in the institute. Other important stakeholders in a TES are recruiters and parents. Recruiters absorb the quality students of an institute into their organisation, whereas the parents supply the students to be imparted quality training in an institute.

4 Research objectives

It is evident from the foregoing discussion that the attributes of service quality vary in different service settings. The attributes diverge among stakeholders even in a particular service setting. The education sector exhibits a multiple-stakeholder situation in which stakeholders perceive different points of view with regard to quality of education. Therefore, it is very difficult for the administrators of a TES to meet the service requirement of all the stakeholders. Hence, there is a need for deciding the minimum number of common service items that suit key stakeholders so that the administrators can focus on these items for improving the quality of education. To address these issues, the following objectives can be drawn up for this study:

- to develop an instrument for measuring service quality in the technical education sector
- to determine the minimum number of common items of service quality capable of addressing the concerns of key stakeholders
- to test the adequacy of neural networks for modelling the customer evaluation of service quality in education.

5 Development of EduQUAL

SERVQUAL is the most extensively used service-quality measurement instrument because of its easiness to use, possession of simple structure and capability of generalisation. Since quality of service largely depends on human behaviour, the quality dimensions of a measuring instrument vary with service settings. For example, 'empathy'

and ‘responsiveness’ are significant in the healthcare sector, whereas ‘reliability’ is important in transportation. Similarly, the components of quality in a fast-food restaurant are very different from those on a railway or a bank or a holiday resort. Therefore, quality of service is very difficult to define precisely because the service provider generally provides utility, not objects as in the case of the manufacturing sector. The diverse components of the service sector make its quality control and improvement more difficult to generalise. Therefore, SERVQUAL dimensions are modified in order to suit the particular service settings. Sometimes the number of dimensions or items under each dimension is modified to suit a particular application (Weitzel *et al*., 1989; Saleh and Ryan, 1991). In the education sector, the persistence of intangibility and lack of physical evidence of service make perceptions of service quality a complex composition, and its analysis becomes difficult. TES is characterised as multiple stakeholders with different backgrounds and varied behavioural patterns. In order to evaluate the quality at the aggregate level fitting to most of the important stakeholders, an attempt has been made to propose a new instrument known as EduQUAL using SERVQUAL as a basis. A pilot study has been conducted by consulting a group of experts in the field of the technical education system. Considering the views of the experts and the quality items mentioned in the literature, a questionnaire containing 43 survey items was prepared (Table 1).

Table 1 Requirements of the stakeholders (service items)

Service items		*Source*
1	Problem-solving skill	Owlia and Aspinwall (1998)
2	Well-equipped laboratories with modern facilities	Redfern (1980), Ashworth and Harvey (1994), Horne and Pierce (1996), Owlia and Aspinwall (1998)
3	Training on state-of-the-art technology	Proposed by experts
4	Effective office management	Owlia and Aspinwall (1998)
5	Knowledge of official procedures	Owlia and Aspinwall (1998)
6	Cleanliness, orderliness, systematic and methodical	Proposed by experts
7	Adequate facilities/infrastructure to render service	Proposed by experts
8	Faculty expertise	Horne and Pierce (1996), Owlia and Aspinwall (1998)
9	Adequacy of subject teacher	Owlia and Aspinwall (1998)
10	Good communication skill of academic staff	Proposed by experts
11	Comprehensive learning resources	Proposed by experts
12	Training in a well-equipped communication laboratory	Proposed by experts
13	Adaptability to modern techniques	Proposed by experts
14	Design of course structure based on job requirement	Proposed by experts
15	Adequacy of supporting staff	Owlia and Aspinwall (1998)
16	Instructional/educational leadership	Scheerens (1992), Nadeau (1993), Spanbauer (1995), Lozier and Teeter (1996), Tang and Zairi (1998)

Table 1 Requirements of the stakeholders (service items) (continued)

Service items		*Source*
17	Effective classroom management	Krajewski *et al*. (1983), Trethowan (1987), Bollington *et al.* (1990) and Horne and Pierce (1996)
18	Opportunities for campus training and placement	Harvey and Knight (1996)
19	Information sharing and exchange	Proposed by experts
20	In service training and development of supporting staff	Proposed by experts
21	Faculty's rapport with student	Redfern (1980)
22	Autonomy/freedom of work	Marchington (1992)
23	Recognition of students/faculty/staff	Trethowan (1987)
24	Courteousness and willingness to help	Owlia and Aspinwall (1998) and Raisbeck (1994)
25	Appropriate classroom hours	Reid *et al*. (1987)
26	Maximum learning time	Scheerens (1992)
27	Academic, residential and recreational facilities	Proposed by experts
28	Aesthetic view of facilities	Proposed by experts
29	Encouragement for sports, games and cultural activities	Proposed by experts
30	Enhancement of knowledge	Proposed by experts
31	Extra academic activities	Proposed by experts
32	Adherence to schedule	Tomlinson (1980)
33	Clarity of course objectives	Proposed by experts
34	Adherence to course objectives	Proposed by experts
35	Practical orientation in education	Owlia and Aspinwall (1998)
36	Faculty available regularly for students' consultation	Raisbeck (1994)
37	Prompt service of the supporting staff	Proposed by experts
38	Ease of access to the institution	Owlia and Aspinwall (1998)
39	Close supervision of students' work	Horne and Pierce (1996)
40	Proper monitoring system and evaluation procedure	Harvey and Knight (1996)
41	Record keeping on performances	Krajewski *et al.* (1983)
42	Transparency of official procedure, norms and rules	Scheerens and Bosker (1997)
43	Sense of social obligation	Proposed by experts

5.1 *Data collection*

Data were collected from students, alumni, parents and recruiters of different technical institutions (both private and government) across India through e-mail/postal mode/personal contact by attaching the questionnaire comprising 43 items on expectations as well as perceptions related to quality of service delivered by their organisation. The respondents were requested to answer in a Likert-type scale from 1 to 7 (1, strongly disagree and 7, strongly agree). The final question of whether the stakeholders would recommend to their friends and relatives to study in this institute was asked and treated as the output of the 43 questions. The lists of institutions, students, alumni and industries were collected by accessing different websites and personal contacts. Stratified sampling was used for random selection of study units from various groups formed based on similarity in certain characteristics. The detailed information of the survey design is shown in Table 2.

The survey was conducted through a different mode of collecting responses over a period of six months (from December 2004 to June 2005). It was carried out in the four zones of the country, *viz.* (east, west, north and south). For the students' survey, a total of 589 questionnaires were sent and 448 responses (76%) received. Responses were screened based on completeness, rational scoring and adherence to scale. Finally, 408 (nearly 69%) responses were considered for further analysis. For the alumni's survey, 478 questionnaires were sent, 257 responded (52%) and the usable responses were 250 (nearly 50%). Similarly, for the parents' survey, 478 questionnaires were sent and 262 responses (55%) were received, out of which 246 (52%) were used for analysis. For recruiters, a total of 286 questionnaires were sent, 124 responses (43%) were received and 120 responses were considered for further analysis.

5.2 *Data analysis*

The useful responses (1024) were tested to examine validity and reliability of the scale so as to obtain a quantitative and statistically proven identification of requirements of the stakeholders. The test for quantitative validity was conducted by factor analysis of the 43 proposed variables using the Principal Component Method, followed by varimax rotation to ensure that they were important and suitable for the model using SPSS 13.0 software. Twenty-eight items that loaded more than 0.5 were kept under five dimensions, *viz.* Learning Outcomes, Responsiveness, Physical Facilities, Personality Development and Academics, as shown in Table 3. The 28 items under five dimensions constituted various relevant variables for the proposed instrument, EduQUAL, to measure education quality in a technical education system. The 15 items that failed to get loaded more than 0.5 (effective office management, knowledge of official procedures, adequacy of supportive staff, instructional/educational leadership, information sharing and exchange, faculty's rapport with students, autonomy/freedom of work, in-service training and development of faculty and supporting staff, appropriate classroom hours, maximum learning time, clarity of course objectives, adherence to course objectives, ease of access to the institution, proper monitoring system and evaluation procedures, record keeping on performance) were excluded from further consideration. The percentage of total variance explained was found to be 75%, which is an acceptable value for the principal component varimax-rotated factor-loading procedure.

Table 2 Details of questionnaire survey

Stakeholders	*Mode of obtaining responses*	*East*		*West*		*North*		*South*	
		Questionnaire sent	*Response obtained*	*Questionnaire sent*	*Response obtained*	*Questionnaire sent*	*Response obtained*	*Questionnaire sent*	*Response obtained*
Students	Postal	25	08	10	02	18	06	25	11
	E-mail	52	31	76	54	33	21	112	87
	Personal contacts	158	158	20	20	15	15	45	45
	Total	235	197	106	76	66	32	182	143
Alumni	Postal	23	06	15	02	20	05	32	10
	E-mail	189	113	65	26	54	32	78	42
	Personal contacts	14	14	–	–	02	02	05	05
	Total	226	133	80	28	76	39	115	57
Parents	Postal	86	38	43	24	32	10	44	17
	E-mail	42	16	57	38	85	52	63	41
	Personal contacts	18	18	05	05	–	–	03	03
	Total	146	72	105	67	117	62	110	61
Recruiters	Postal	25	05	35	11	22	08	25	06
	E-mail	13	04	72	29	27	12	48	30
	Personal contacts	10	10	02	02	03	03	04	04
	Total	48	19	109	42	52	23	77	40

Table 3 Factor analysis of EduQUAL items (Cronbach Alpha = 0.950)

Dimensions		*Items*	F_1	F_2	F_3	F_4	F_5
Learning outcomes ($\alpha = 0.860$)	1	Training on state-of-the-art technology	0.809				
	2	Practical orientation in education	0.779				
	3	Adaptability to modern techniques	0.690				
	4	Design of course structure based on job requirements	0.644				
	5	Problem-solving skills	0.625				
	6	Sense of social obligation	0.556				
Responsiveness ($\alpha = 0.752$)	7	Prompt service at service departments		0.856			
	8	Courteousness and willingness to help		0.739			
	9	Cleanliness, orderliness, systematic and methodical		0.695			
	10	Transparency of official procedure, norms and rules		0.556			
	11	Adequate facilities/infrastructure to render service		0.533			
Physical facilities ($\alpha = 0.909$)	12	Well-equipped laboratories with modern facilities			0.762		
	13	Comprehensive learning resources			0.752		
	14	Academic, residential and recreational facilities			0.750		
	15	Aesthetic views of facilities			0.658		
	16	Training in a well-equipped communication laboratory			0.613		
	17	Opportunities for campus training and placement			0.558		
	18	Effective classroom management			0.533		
Personality development ($\alpha = 0.897$)	19	Encouragement for sports, games and cultural activities				0.874	
	20	Enhancement of knowledge				0.809	
	21	Adherence to schedule				0.753	
	22	Extra academic activities				0.602	
	23	Recognition of the students				0.527	
Academics ($\alpha = 0.861$)	24	Adequacy of subject teachers					0.856
	25	Available regularly for students' consultation					0.785
	26	Close supervision of students work					0.632
	27	Expertise in subjects and well-organised lectures					0.583
	28	Good communication skill of academic staff					0.548

The internal consistency or the reliability of the actual survey data of stakeholders (students, alumni, parents and recruiters) was tested by computing Cronbach's Alpha. The values of alpha for five dimensions were 0.860, 0.752, 0.909, 0.897 and 0.861 and the combined alpha value for all the items is 0.950 (Table 2). Since the values of alpha well exceeded the obligatory requirement of 0.70 or above, they demonstrated internal consistency of the established scales (Nunnally, 1988). The value of Kaiser-Meyer-Olkin (KMO), which is a measure of sampling adequacy, was found to be 0.782. This indicated that the factor analysis test had proceeded correctly and the sample used was adequate because the minimum acceptable value of KMO is 0.5 (Othman and Owen, 2001). Therefore, it can be concluded that the matrix did not suffer from multi-collinearity or singularity. The results of the Bartlett test of Sphericity was highly significant (sig. = 0.000), implying correctness and suitability of factor analysis processes for testing multidimensionality (Othman and Owen, 2001). Thus, the statistical and factor analysis tests showed the proposed items and dimensions of the instrument EduQUAL were sound enough to measure the service quality in a technical education system and hence could be used for further analysis.

The instrument consisted of 28 important items as listed in Table 2 and classified into five dimensions. The five dimensions may be defined as follows:

1 *Learning outcomes* – ability to provide the promised service dependably and accurately

2 *Responsiveness* – willingness to help customers, provide prompt service

3 *Physical facilities* – physical facilities, equipment, personnel and communication material

4 *Personality development* – overall development of students' personality, enhancement of knowledge

5 *Academics* – expert faculties, individualised attention to the customer.

6 Measurement of service quality

The human decision-making process can be modelled using neural networks, as such networks have the capability to predict an output, classify a given set of inputs into different groups (known as the pattern recognition) and incorporate heuristic criteria (Baily and Thompson, 1990). As neural networks can effectively exploit and represent the non-linear relationship between consumer satisfaction and their perception of the service, it can be used for modelling a customer's decision-making process (Mittal *et al*., 1998). In this study, four neural network models were designed for the analysis and evaluation of service quality with inputs like customer expectations, customer perceptions and the gaps.

6.1 Network parameters

The responses obtained from different stakeholders for the 28 items with regard to perceptions and expectations pertaining to TES were used to measure the quality through the application of the back-propagation algorithm of neural networks. The back-propagation module of the neural network package NeuNet Pro Version 2.3[1] was

used for training and testing of survey data owing to its fast generalisation capability. The network consists of three layers having a desired number of nodes in the input (I) as well as a hidden layer and a single node in the output layer. A single question regarding the overall customer evaluation of the service quality is considered to be the output. As per the software recommendations, the number of nodes in the hidden layer (H) is decided by the relation below:

$$H = 2\sqrt{(I+1)} \tag{1}$$

Normalisation of raw data was carried out to obtain values between 0 and 1 for expressing all data in a common scale. Learning rate less than 0.1 and momentum parameter near to zero were set during the training phase. Seventy-five percent of data for each stakeholder was considered for training and the rest data were used for testing. The numbers of correct outputs were noted till the Root Mean Square Error (RMSE) is minimised to a reasonable value.

6.2 Design of models

Usually, four models – Perception minus Expectation gap (P-E gap), Expectation minus Perception gap (E-P gap), Perception-only (P-only), and Expectation and Perception (E&P) models – are used to predict service quality. However, the performance of various models in relation to the predictive power of service improvement widely differs depending on the type of application (Parasuraman *et al*., 1985; 1988; Cronin and Taylor, 1994; Behara *et al*., 2002*)*. As service quality items vary from one sector to another, the best model may likely differ from sector to sector. Therefore, neural network models, when tested in a different service sector with different survey items, may indicate significantly different results. Therefore, it was decided to test all four well-known models in TES.

1 Model-I (P-E gap model)

   In this network model, the input is defined using the traditional SERVQUAL-based gap that means perceptions of customers minus the expectations (Parasuraman *et al*., 1988). This resulted in 28 input nodes, a hidden layer with 11 nodes and an output layer having only one node representing the overall evaluation of service quality. Using the training sample (75% data), the network was run till RMSE was minimised. Then the network was tested with test data (25% data) and finally the percentage of correct outputs was noted.

2 Model-II (P-only model)

   This model uses customer perceptions-only as input to the network in accordance with the guiding principle of SEVPERF, a service-quality measuring instrument, which argues that perceptions of the customer are more important than the gap between their perceptions and expectations. The perception data were trained to obtain the minimum root mean square error and finally tested to get the percentage of correct output.

3 Model-III (E-P gap model)

Generally, it is assumed that most customers enter a service situation with some expectations (Behara *et al*., 2002). These expectations are formed either from previous experiences of the same or similar service or simply expectations generated by the customer independently. So the customer usually undertakes a service experience with some preconceived expectations and thereafter develops a perception of that experience. Hence, service quality could be measured as expectations minus perceptions or the E-P gap. A positive E-P score implies that customer expectations are not met, whereas a negative score in this gap indicates a delighted customer. The values of the gap for the 28 items of EduQUAL were used as the input data for this network. The training and testing of the E-P data were carried out in a similar fashion to that mentioned earlier.

4 Model-IV (E&P model)

Customer expectations are generally accepted as a part of the service experience, but their exact role in the overall evaluation of service quality is still controversial (Behara *et al*., 2002). Therefore, the interactions of expectations and perceptions independently may be considered without a predefined relationship between them. In this case, the input layer of this neural network model consisted of 56–28 input data for expectations and 28 for perceptions. The training and testing of data were carried out in a similar fashion.

6.3 Performance of the models

Each of the above models for a particular stakeholder was run varying the learning parameter, momentum parameter and number of cycles till RMSE is minimised. A model is said to perform best when the percentage of correct outputs is higher for the same RMS value. The learning parameters lay between 0.07 and 0.1, whereas the momentum parameter approached zero (0.01 to 0.03). The number of cycles varied from model to model for different stakeholders. The value ranged from 18 680 to 293 380 for students, whereas it ranged from 3730 to 30 855 for alumni. But for parents and recruiters, the training cycles ranged from 2760 to 7975. The RMSE ranged from 0.15 to 0.25 for students, alumni and parents whereas it ranged from 0.07 to 0.08 for recruiters. Considering the maximum percentage of correct outputs with minimum RMSE, the P-E gap model was found to be the best model for predicting correct output for all the stakeholders. The values of correct outputs for different stakeholders for the P-E gap model were found to be 77%, 90%, 70% and 82% for students, alumni, parents and recruiters, respectively. The parameters used in all four models are shown in Table 4.

As a matter of fact, the comparative study of the four models suggests that the P-E model has better predictive power for all the important stakeholders in a TES. The second-best model was found to be the E-P model for students and alumni, whereas it was the P-only model for parents and recruiters. This indicates that parents and recruiters do not overemphasise expectations but judge the quality of education in an indirect way from their wards and jobseekers. It is worthy of mention that the E&P model was the worst among all the models for all stakeholders considered in this study. Since statistical evidence also favours EduQUAL, it may be used for predicting service quality in TES

and identifying deficiencies in the system according to the four important stakeholders of the system. Sensitivity analysis of the best model will help to identify the deficiency in the system.

Table 4 Results of neural network models

Stakeholders	*Neural network models*	*Learning parameter*	*Momentum parameter*	*Number of cycles*	*RMS error*	*Percentage of correct output*
Students	P-E gap	0.10	0.02	293 380	0.21	77*
	P-only	0.09	0.03	18 680	0.22	62
	E-P gap	0.08	0.01	461 380	0.25	69
	E & P	0.09	0.02	379 195	0.21	69
Alumni	P-E gap	0.07	0.01	21 775	0.15	90*
	P-only	0.09	0.03	30 855	0.15	60
	E-P gap	0.08	0.01	17 725	0.17	70
	E & P	0.10	0.03	3730	0.19	60
Parents	P-E gap	0.08	0.02	4150	0.15	70*
	P-only	0.08	0.01	7975	0.17	70
	E-P gap	0.09	0.03	6500	0.18	70
	E & P	0.10	0.02	3980	0.19	69
Recruiters	P-E gap	0.09	0.03	7095	0.07	70*
	P-only	0.09	0.01	3350	0.08	70
	E-P gap	0.09	0.03	7320	0.07	50
	E & P	0.09	0.03	2760	0.07	50

Note: * indicate the highest percentage of correct output

7 Sensitivity analysis

In order to find the robustness of the proposed model, sensitivity analysis was carried out for the best model (the P-E model). Sensitivity analysis is used to study the impact of changes in service performance along the various items (inputs) in customer evaluation of service quality (output). The inputs in the test samples are varied one at a time systematically, up and down 10% (±10%) from its base value holding other items at their original values. The scaled change in output is calculated with the current input increased by 10% and the current input decreased by 10%. The scaled change in output is given by:

$$\textit{Scaled change in output} = \frac{\textit{Scaled output for } 10\% \textit{ increase in input} - \textit{scaled output for } 10\% \textit{ decrease in input}}{2} \quad (2)$$

Thus, the results obtained are the scaled output change per 10% change in input. The calculation is repeated for every input (P-E gap) and for every fact and then averaged across all the facts, yielding a single-mean scaled change in output for each input service criterion (Table 5).

Table 5 Sensitivity analysis

Inputs		*Students*	*Alumni*	*Parents*	*Recruiters*
1	Training on state-of-the-art technology	–0.091[7]	–0.154[3]	–0.234[2]	–0.065[9]
2	Practical orientation in education	–0.004[16]	–0.032[10]	+0.038	–0.030[12]
3	Adaptability to modern techniques	+0.123	+0.132	+0.042	–0.120[2]
4	Design of course structure based on job requirements	–0.214[4]	+0.031	+0.208	+0.062
5	Problem-solving skills	–0.008[15]	+0.066	+0.002	–0.185[1]
6	Sense of social obligation	+0.033	–0.023[13]	+0.109	+0.104
7	Prompt service at service departments	+0.062	–0.009[14]	–0.123[8]	+0.007
8	Courteousness and willingness to help	–0.088[9]	–0.112[4]	–0.028[14]	+0.004
9	Cleanliness, orderliness, systematic and methodical	–0.135[6]	–0.063[8]	–0.133[6]	+0.018
10	Transparency of official procedure, norms and rules	+0.240	+0.024	–0.081[10]	+0.068
11	Adequate facilities/infrastructure to render service	+0.032	+0.002	+0.240	+0.031
12	Well-equipped laboratories with modern facilities	–0.300[2]	–0.009[15]	+0.039	+0.060
13	Comprehensive learning resources	–0.009[14]	–0.075[6]	–0.004[15]	–0.033[11]
14	Academic, residential and recreational facilities	–0.032[11]	+0.046	–0.079[11]	+0.090
15	Aesthetic views of facilities	+0.026	+0.027	+0.139	+0.041
16	Training in a well-equipped communication laboratory	+0.070	–0.088[5]	+0.189	–0.026[13]
17	Opportunities for campus training and placement	–0.089[8]	–0.062[9]	–0.075[12]	–0.070[8]
18	Effective classroom management	+0.065	+0.003	–0.244[1]	–0.077[6]
19	Encouragement for sports, games and cultural activities	–0.140[5]	–0.290[1]	+0.087	–0.009[14]
20	Enhancement of knowledge	+0.020	+0.087	+0.078	–0.074[7]
21	Adherence to schedule	+0.088	+0.106	–0.056[13]	+0.160
22	Extra academic activities	+0.556	+0.042	+0.091	+0.029
23	Recognition of the students	–0.030[12]	–0.026[12]	–0.179[3]	+0.088
24	Adequacy of subject teachers	+0.551	+0.031	+0.031	+0.008
25	Available regularly for students' consultation	–0.331[1]	+0.052	–0.124[7]	–0.099[4]
26	Close supervision of students' work	–0.023[13]	–0.028[11]	–0.151[4]	–0.060[10]
27	Expertise in subjects and well-organised lectures	–0.045[10]	–0.185[2]	–0.144[5]	–0.087[5]
28	Good communication skill of academic staff	–0.226[3]	–0.068[7]	–0.115[9]	–0.113[3]

Notes: 1. The negative score for average scaled change in output scores per 10% variation in inputs is the norm. Percentage of negative scores for various stakeholders: Students – 57%; Alumni – 53%; Parents – 53%; Recruiters – 50%.

2. The superscripts indicate ranking of items in ascending order of negative values.

Increasing input (gap) from its base value result in decrease in service quality owing to the widening of the gap, whereas a reduction in the gap indicates an evaluation of increased service quality. Logically, the net effect of change in input (gap) results in a negative score for average scaled change in output. About 50% to 60% of input items produced negative service quality changes, as expected. The percentage of items producing negative scores were 57%, 53%, 53% and 50% for students, alumni, parents and recruiters, respectively. However, positive or increased service quality is also obtained in all the cases. This irregularity may be attributed to the noisiness of the survey data. Noisy data exists when customers responding to a survey have a similar evaluation on individual questions but different evaluation of the overall service quality. This results in similar input data for the neural network with very different corresponding outputs.

The values of scaled change in output for items having negative scores for each stakeholder are shown as superscript in ascending order in Table 5. The larger, negative mean effect value indicates a large change in the overall evaluation of service quality (outputs) with the same percentage change in gaps (inputs). Therefore, the items resulting in a large, negative mean effect are treated as deficient items where improvements are needed. The most important items that the students suggested for improvement, having evaluation scores less than –0.1 (threshold value), were items 25 (available regularly for students' consultation), 12 (well-equipped laboratories with modern facilities), 28 (good communication skill of academic staff), 4 (design of course structure based on job requirements), 19 (encouragement for sports, games and cultural activities) and 9 (cleanliness, orderliness, systematic and methodical). Alumni cited items 19 (encouragement for sports, games and cultural activities), 27 (expertise in subjects and well-organised lectures), 1 (training on state-of-the-art technology) and 8 (courteousness and willingness to help) as the most important quality factors that needed to be improved, using a threshold value of –0.1. However, parents proposed nine out of fifteen items having a score of less than –0.1. These are listed as items 18 (effective classroom management), 1 (training on state-of-the-art technology), 23 (recognition of the students), 26 (close supervision of students' work), 27 (expertise in subjects and well-organised lectures), 9 (cleanliness, orderliness, systematic and methodical), 25 (available regularly for students' consultation), 7 (prompt service at service departments) and 28 (good communication skill of academic staff). The parents seem to be suggesting ambitious improvement plans to provide quality education in a TES. Similarly, the recruiters opined that service items such as items 5 (problem solving skills), 3 (adaptability to modern techniques) and 28 (good communication skill of academic staff) badly need improvement.

It is evident from Table 5 that there are six common items rated negative by all stakeholders. The six common items are training on state-of-the-art technology (Item 1), comprehensive learning resources (Item 13), opportunities for campus training and placement (Item 17), close supervision of students' work (Item 26), expertise in subjects and well-organised lectures (Item 27) and good communication skill of academic staff (Item 28). This implies that these six items have a strong effect on service quality and the policymakers of the TES must focus on these areas for improving the satisfaction level of potential stakeholders. It may be concluded that the neural network developed in this study to model quality of education is adequate for predicting the overall evaluation of the technical education system by their stakeholders but not robust enough for sensitivity analysis, indicating a need for future research.

8 Conclusions

The major contribution of this paper is providing a systematic integrated approach for modelling customer evaluation of service quality applied to technical education. As the quality of service largely relates to human behaviour, the quality dimensions and items under each dimension of the measuring instrument widely differ depending on the application to the type of service setting. Most of the service sectors deal with a single customer base and customer satisfaction is of prime importance for them. However, the stakeholders in an educational setting range from students to recruiters, with varying levels of interaction with the system and expectations from the system. An educational set-up must satisfy the needs of such a wide range of stakeholders. This results in difficulties for implementing quality control and improvement programmes and policy planning. Therefore, it is advisable to identify the minimum number of service items that suit all the stakeholders before implementing any quality improvement programme. To this end, EduQUAL, a survey-based model, has been specially developed to suit a technical education system. A survey was conducted in different technical institutions across India for collecting data from four types of stakeholders: students, alumni, parents and recruiters. The survey data were tested for reliability by finding out Cronbach's Alpha and validated using factor analysis followed by varimax rotation. Factor analysis makes it possible to define the five dimensions of the instrument and lists quality items conforming to the needs of the four types of stakeholders.

As artificial neural networks are capable of simulating human evaluation processes adequately, four neural network models, P-E gap, P-only, E-P gap and E&P models, were developed. The responses obtained from stakeholders for the individual service items served as inputs to the different neural network models. It was observed that the P-E gap model is the best model for predicting the service quality for all stakeholders considered in this study. The study reconfirms that the traditional P-E gap for defining quality outperforms other gap models. The second-best model for students and alumni happened to be the E-P gap model. This implies that expectations do and should play a role in the measurement of service quality. However, our study suggests that E&P model should be used cautiously for predicting quality, as its performance is not satisfactory as far as education quality study is concerned. The second-best model for parents and recruiters was the P-only model, implying that even if they have expectations, these does not significantly affect their evaluation process. The reason is that the expectations are derived in an indirect way through word-of-mouth or some other source, without their having any direct service experience.

The final step in our study demonstrates the use of sensitivity analysis of the best model to identify the deficient items suggested by all four stakeholders for providing guidelines to the policymakers. The areas where the improvements in the service are required for a TES in the context of this study are training on state-of-the-art technology (Item 1), comprehensive learning resources (Item 13), opportunities for campus training and placement (Item 17), close supervision of students' work (Item 26), expertise in subjects and well-organised lectures (Item 27) and good communication skill of academic staff (Item 28). The present technical education system throughout the country urgently needs to modernise the syllabi and course curriculum, keeping in view rapid technological growth. Mostly, the institutions suffer from shortage of learning resources like books, journals, software and training modules, causing serious impediments

to the independent growth of the students. The location disadvantage and lack of industry-institute interaction restricts job opportunities of the students. As far as teaching staffs are concerned, vacancies exist in a large number of institutions owing to difficulties in getting the right faculty. Moreover, it is also difficult to retain the existing faculties because they are not motivated properly to instill pride in their profession in them.

Although this study demonstrates the methodology for modelling customer evaluation of service quality in the education sector at an aggregate level, the approach is quite general and can be applied to any specific organisation. However, we recommend identification of customers at the first step and then meticulously finding out their requirements. The next step is to design a measuring instrument for particular application which should be used only after validating through statistical tests. In the third step, the appropriate neural network model may be developed and sensitivity analysis of the model carried out for identification of current deficient items. The neural network models developed in this study are adequate for predicting the evaluation of customers. However, sensitivity analysis of neural network models indicates that the models are not robust enough. Therefore, future research in this direction may be carried out.

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Note

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