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Gender Disparity in Barriers Perceived Among Pre-Engineering Students at FSc. Level

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Abstract

Background. High attrition rate is prevalent in engineering field due to lack of interest and academic dissatisfaction among students which may be due to a number of barriers perceived by them in pursuing engineering during course of their education. Therefore, the major objectives for this research were to identify those perceived barriers, develop an indigenous valid and reliable measure for identifying perceived barriers in pursuing pre-engineering, to quantify the most encountered barrier, and establishing impact of perceived barriers on academic satisfaction. Present research was accomplished in two phases.

Method. A 27 items Perceived Barriers in Pursuing Engineering Scale was developed by utilizing empirical approach in item generation based upon focus group discussions of students who had done pre-engineering in high secondary school (HSS) and studying currently in engineering (7 FGDs) and non-engineering field (5 FGDs) at undergraduate level and interviews of teachers (N = 7) teaching in pre-engineering level followed by evaluation of 10 Subject Matter Experts. Exploratory factor analysis on sample of students studying at pre-engineering HSS level (N = 324) resulted in unidimensional scale.

Results. Most frequently faced barriers by participants were computed by using Chi Square on each item with gender. Male students reported significantly higher scores on barriers than female students.

Conclusion. This research has important implications for stakeholders seeking to rectify low enrollment rates in engineering.

Keywords. Perceived barriers, pre-Engineering, gender, exploratory factor analysis, scale development.

Introduction

From productivity to increasing efficiency, from saving lives to feeding people affectively, the modern world and the lives of an exponentially growing population are increasingly dependent on the field of engineering and technology. Science, Technology, Engineering, and Mathematics (STEM) fields are crucial for developing industries that increase global competitiveness and usher in prosperity (Kayan-Fadlelmula et al., 2022), therefore, countries invest in STEM education to prepare students for careers in these fields.

In spite of the importance of STEM studies, students often show a lack of persistence, and interest in these fields. STEM enrolments are low, dropouts are high, and the general STEM pipeline of students has been highlighted as an issue that needs to be addressed (Estrada et al., 2018). There is need to identify whether gender is affecting students' decision to opt for engineering.

Career Decision Making About Engineering

The situation is especially worrisome in Pakistan when it comes to engineering because even though Pakistan has number of engineering universities, but trained engineers lack practical approach needed to solve real problems. The barriers and deficits need to be traced back from where the engineering education starts, that is the pre-engineering at high school level where the critical decision making for opting a career is made (Afsar & Jami, 2020).

Career decision making and a choice of subject is the greatest challenge for all individuals' men or women. This difficulty is compounded by the fact that these choices have to be made as early as possible. Especially in Pakistan's educational system, students have to opt for the combination of pre-engineering subjects in grade 11 if they want to pursue careers in engineering. This choice of a career or field is a crucial moment in a students' life since wrong decisions can become one of the major life-long regrets. Research and valuable assessments have been suggested to identify the factors influencing the students opting engineering as education and career (Kayan- Fadlelmula et al., 2022).

The dilemma of how, when, and by whom to guide, teach and explore the technological fields and prepare the students at school level for technological domains has not yet been solved although efforts have been made in identifying the factors affecting STEM fields (Nurtanto et al., 2020). Consistent relation of barriers with gender and contextual support have been examined.

Social Cognitive Career Theory (SCCT) provides different ways to identify career choices, interest, success achievement as well as academic and occupational satisfaction but gender is held really important in all these prospects. Career decision making is a reciprocal process where the person and the environment reciprocate the influence. It is considered crucial as there are number of factors involved. Taking a decision, future orientation, the persistence in that career, the journey they will experience, and the feedback they receive from significant others are all important. Number of factors are considered to be important students have to compromise their personal interest as posited by SCCT due to contextual factors like support from significant others, perceived barriers, and gender disparity etc. This theory identifies barriers as one of the important reasons for failure and dissatisfaction in academia (Turner et al., 2019). It is pertinent to understand the gender role in this perspective as engineering is considered a more masculine field and less number of females enroll in this discipline.

Barriers faced by Engineering Students

The high attrition rate and the lack of interest is mostly attributed to the factors such as barriers or hindrances in the course of engineering education, traced back to pre-engineering and that is mostly influenced by specific gender (Lent & Brown, 2008).

Barriers are those events or circumstances related to the individual or the environment which makes advancement challenging. So, barriers include the intrapersonal or environmental factors that causes hindrance to any progress (referring to the context). Specifically, for the engineering students, hurdles and problems faced by the individual in pursuit of engineering is known as barriers (Lent et al., 2008).

Researchers have identified different barriers in the engineering education and suggests the minimizing of such factors. One such study indicated that students face hurdles and problems in persuasion of engineering (Sørensen et al., 2018). In another evidence, teachers' lack of qualification may lead to low quality teaching of the dynamics of such important fields (Xu & Li, 2021).

The nature of barriers faced by students deserves a closer look. The secondary school (K-12), which is an equivalent of the FSc level education in Pakistan, plays a major role in producing potentiated engineers. The baseline has to be strong as it serves as a foundation for strong and refined career aspirants who could be role models for the next generation as well. To achieve this goal there is a need to focus on the basic concepts of engineering and mathematics which is said to be a major lacking at pre-engineering level. The high attrition rate, lower persistence and under-representation of females can also be attributed to the lack of basic information and conceptual clarity of the students.

Polastri and Alberts (2014) in their research revealed that lack of mathematical skills is a major reason of attrition in engineering in US and suggested a revision in the curriculum in engineering education to incorporate the necessary requirements in the curriculum.

The role of barriers is considered by many theorists for career and educational developmental studies and research on perceived barriers has increased noticeably in past decades. Swanson et al. (1996) have suggested that inquiry on barriers has been beset by two major problems, lack of theoretical foundation of the barriers scale, particular measure need to be devised to specifically achieve objective in a contextual setting. Considering the suggestion from Swanson et al. (1996), it was decided to develop a scale that is relatively nomothetic for the particular participants and can focus on the barriers they are facing as a whole in that educational tenure.

Role of Gender

Gender is widely reported in the literature to be an important attribute in considering engineering related studies as it is more identified as a masculine field. The stereotypic threat to female students undermines their attitudes and performances in STEM related subjects and losing the interest in the said fields. Flores et al. (2020) conducted a study on the effect of perceived barriers and other factors in a longitudinal study on 226 boys and 116 girls from engineering where he did not identify the gender role in perceived barriers and suggested that it should be studied. Gender differences has been reported throughout the literature specially in engineering related field and overall STEM education. Although females are under-represented in the engineering field, the reason for which was lower self-efficacy of the females. Therefore, role of gender in perceiving barriers in pursuing engineering at high secondary school level will also be explored.

Rationale of the Study

Although Lent et al. (2001) explained that barriers are subjectively experienced and every person has a different interpretation of barriers. Some students face more barriers than others and succeed more as they are satisfied with the progress they make over time and some with a few hindrances cannot proceed further. But as the educational degree gets harder, the number of barriers are perceived more which leads to dissatisfaction of the students in their educational career. So they suggested to consider multiple factors such as financial constraints, gender differences, peer influence and parental behaviors for analyzing barriers. This suggest the need to develop an instrument that will cater the subjective experience of the students.

To study the barriers faced by the students of FSc., no suitable existing scale was found so there was a need for a measure would be developed that can serve our purpose. Barriers scale for Bachelor's students was available but that was not serving the purpose appropriately. The scale of barriers was developed by the researcher taking the idea from the 18-items scale by Lent et al. (2001).

The researchers intended to use the original scale by Lent et al. (2001) but it was mainly based on bachelors' students which was not valid for FSc. students. Moreover, no available scale could adequately capture the construct that the present research was considering so adaptation was not an option. So, in order to measure the barriers faced by the FSc. pre-engineering students in the Pakistani culture, a decision for development of the scale was taken to study and explore the objectives of the study in a valid and reliable way.

Therefore, the present aim to develop an indigenous instrument for assessing perceived barriers faced by male and female students in pursuing pre-engineering. The method adopted for the present study has been discussed next.

Objectives

The main objectives to be achieved in the study are to:

1. Develop a valid and reliable scale for measuring perceived barriers in pursuing engineering among HSS students studying in pre-engineering.
2. To examine the role of gender in perceived barriers among pre-engineering HSS students.

Hypotheses

1. Girls will perceive more barriers in pursuing engineering as field of study at pre-engineering HSS level than boys.

Method

Development and validation of the Perceived Barriers in Pursuing Engineering Scale was achieved in two phases employing empirical approach (Lent et al., 2001) including: Phase I was scale development and Phase II was validation of the Scale.

Phase 1: Development of Perceived Barriers in Pursuing Engineering Scale

Scale development was carried out in different steps:

Step 1. Focus group discussions (FGDs) and interviews

Step 2. Generation of items through content analysis

Step 3. Selection of items

Step 4. Establishing content validity

Step 1. Focus Group Discussions (FGDs) and Interviews

Sample. This study is part of PhD study of first author. The scale was developed using data from qualitative part of PhD study (already published elsewhere, Afsar & Jami, 2020). Participants included students who had done pre-engineering in HSS were included and they were currently enrolled in engineering (7 FGDs) and non-engineering (5 FGDs) fields at undergraduate level. They were students of 1st and 2nd semesters of BS and BE (for details of sample See Afsar & Jami, 2020). Beside this, interviews of six teachers currently teaching in pre-engineering level were included in the sample (for details of sample See Afsar & Jami 2022). Purposive sampling technique was used in recruiting participants of this phase.

Table 1

Demographic Characteristics of the Sample

Sample	Engineering Students' (N = 7) FGDs	Non-Engineering Students' (N = 5) FDGs	Teachers' (N = 7) Interviews
Course	Undergraduate	Undergraduate	Teaching at Pre-engineering
Gender			
Male	35	26	4
Female	9	4	3
Age	19-23 years	20-24 years	Not specified
City	Islamabad & Rawalpindi	Islamabad & Rawalpindi	Islamabad

FGD and interview guide. FGD guide (29 total. 41 probing questions) and interview guide (16 total, 19 probing questions) were formulated in the light of current literature to explore students' experiences in pre-engineering HSS in retrospect. For example, "What should be the personality trait of a person who wants to pursue engineering? What are the factors that lead students for high/low academic achievement? What is the most difficult decision of your life?". The probing question for this main question was, "Why do you believe it was a difficult decision?" etc. Students were asked about barriers they faced in pursuing engineering later at undergraduate level as some were able to pursue and were studying in BE while others left engineering in undergraduate level and opted social sciences. This helped to pinpoint barriers effectively. Teachers were asked what factors they think act as barriers for HSS in pursuing engineering in higher education level. It included 28 total and 41 probing questions formulated in what, why, and how format to make respondent respond in detail which covered the domains of personality, interest, attitude, aptitude, achievement, motivation, self-efficacy, social support, values, barriers, satisfaction, burnout and barriers.

Procedure. Permission was taken from the Federal Education Directorate and the heads of each educational institute to conduct interviews with the teachers in college premises. Interview guide and purpose of the study were shared with the heads of the institutes and respective teachers to seek their consent. The same procedure was followed for accessing students in university settings to conduct FGDs. After informing all about the objectives of the study, promise to maintain confidentiality and anonymity of their responses, interviews and FGDs were conducted and audio-recorded with their permission. In FGDs, a trained MPhil scholar facilitated in conducting FGDs. It took 35 min. to 1 hour 20 min. to conduct each interview and FGD. Later, audio-recorded data was transcribed and content analysis was carried out.

Step 2: Generation of Items

For measuring the barriers faced by the students at pre-engineering HSS to pursue engineering later, 36 items were developed initially from the content analysis of FGDs and interviews. These were barriers that were commonly appearing in both types of FGDs and interviews (for example, parental influence in subject choices, lack of support, content and curriculum related barriers, institutional barriers etc.).

Step 3: Selection of Items

The item pool was evaluated in a committee comprising of six teachers teaching at pre-engineering level. According to them, some items were more appropriate for bachelor's level instead of pre-engineering level so those items were excluded from the initial form of the Scale. For example, the item "semester system was not compatible with the annual system of the intermediate level of education" was removed.

The scale, subsequently, was comprising of 27 quantitative items with an additional item 28 included to explore "other barriers" to identify barriers faced by the students that might have been overlooked. The scale was designed to be a 5-point Likert scale with instructions "Here we are interested in knowing how much suffering each barrier or problem that you are probably facing in pursuing pre-engineering". The response options included: *Very little/Not at all* coded as 1, *A little* as 2, *Moderately* as 3, *Quite a bit* as 4, and *Extremel*y as 5. High score would present more barriers faced in pursing engineering as field while studying at pre-engineering HSS. The instructions given were, "Here we are interested in knowing how much suffering in each barrier or problem you are probably facing in pursuing pre-engineering".

Step 4: Establishing Content Validity

Content validity was established. Subject Matter Experts (who were teaching at high school level to pre-engineering students; N = 6) were approached and objectives were clearly defined. They were requested to select items carefully on the basis of construct relevance, clarity, and representativeness. Modifications were suggested in the initial item pool in items 1, 2, 9, and 12 including rephrasing and completion of statement/words to convey the concept meaningfully, which were done in the final scale set (See Appendix R). The formula of content validity ratio used for determining the validity was

$CVR = (Ne - N/2)/(N/2)$

Where Ne is the number of panelists indicating an item as "essential" and N is the total number of panelists. The numeric value of content validity ratio was determined by Lawshe Table (Lawshe, 1975). The recommended cut-off scores from six to eight experts was at least .83 (Lynn, 1986). The content validity for the scale for majority of items was 1. However, since the CVR for 9 were related to annual and semester system, choice of institutes, gender stereotypes, gender differences attitude, selection in university, poor writing, domestic issues, and boarding and emotional dependency on parents were below .83, they were discarded from the scale.

Phase 2. Validation of the Scale

Sample

Purposive sampling technique was used to recruit 324 students studying in 1st year and second year of pre-engineering HSS from public and private colleges of Islamabad, Rawalpindi, and Sargodha. Descriptive of the sample characteristics is given in Table 2.

Table 2

Frequencies and Percentages on Demographic Variables of the Sample (N = 324)

Categories	*n* (%)	Categories	*n* (%)	Categories	*n* (%)
Age		Engineering chosen by Self	245 (75.6)	Residence	
15-16	55 (16.9)	By Parents	61 (18.8)	Hostelite	17 (5.2)
17-18	244 (75.5)	Both	1 (.3)	Day Scholar	225 (69.4)
19-20	25 (1.7)	By Others	15 (4.6)	Other	82 (25.3)
Gender		Sought career counseling		Birth Order	
Male	201 (62)	Yes	153 (47.2)	1st	104 (32.1)
Female	123 (38)	No	152 (46.9)	2nd	91 (28.1)
Type of College		General Guidance	19 (5.9)	Only Child	96 (29.6)
Private	55 (17)			Other	32 (9.9)
Public	263 (82)				

A good sample size was achieved to run factor analysis.

Assessment Measures

Following scales were administered along demographic sheet.

Perceived Barriers in Pursuing Engineering Scale. This was developed in Phase 1 of the current study. Barriers are defined as the hindrances and obstacles that are faced by pre-engineering HSS students to pursue engineering as their career or field of study. It has 27 items with 5-point Likert scale on the degree of occurrence where 1 shows *very slightly* and 5 shows *extremely*. The scale had no reverse scored items. The potential range is 27 to 135. High score represents high barriers in pursuing pre-engineering at pre-engineering level.

Procedure. Permission was taken from Federal Education Directorate to collect data from the respective colleges offering pre-engineering at HSS level. Official permission letter from Federal Education Directorate and questionnaires along demographic sheet were shown to head of the colleges to seek their consent to collect data from students studying in pre-engineering HSS. They appointed teachers to facilitate in data collection in classroom setting. Informed consent was obtained from willing participants after sharing objective of the study, right to withdraw, ensuring confidentiality and anonymity of information provided by them. Data was entered into SPSS 22 and analysis was done.

Results

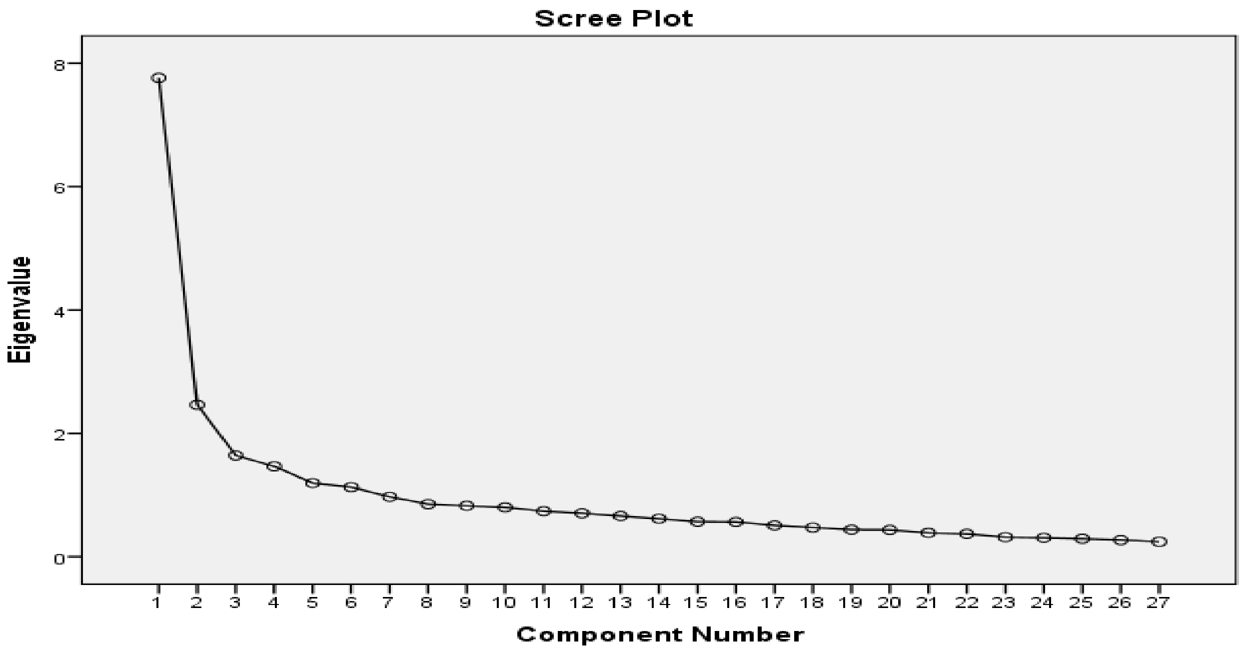
To establish psychometric properties of the Preceived Barriers in Pursuing Engineering Scale, reliability was established through Cronbach alpha; construct validity was established through item-tototal correlations, Exploratory Factor Analysis (EFA). As secondary objective role of gender in perceived barriers was explored on three response levels.

Construct Validity

To determine internal consistency and homogeneity of Perceived Barriers in Pursuing Engineering Scale in measuring the construct, item-to-total correlations is computed for all items. Item-to-total correlations range is .35 - .61 at p < .01 for items 1 to 9 and 25, respectively. All items are significantly positively correlated with total score on the Scale. Principal Component Analysis using Oblique (oblimin) rotation for EFA was used to give structure to the scale and reduce number of the items further (Sürücü et al., 2022). The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, indicating the adequacy of sample and appropriateness of the data for factor analysis is .88. The closer the value of Bartlett's Test of Sphericity is significant, χ^2 (n = 324) = 3236.65 (p < .05), which indicates data's suitability for factor analysis. EFA was run by employing 2, 3, and 4 factor solutions. Each time achieved factor structures were not giving any meaningful picture of the all factors to retain these. Scree plot is given in Figure 1.

Figure 1

Scree plot for Barriers in Pursuing Pre-Engineering Scale.



Finally, unidimensionality of the Scale was checked and Scale was found to be unidimensional as all items loaded on one factor with minimum factor loading of .30. As data was more than 10 times greater than total number of items, therefore .30 is taken to be a fair criterion for retaining items (See Goretzko et al., 2021). All items have .30 and more (See Table 3).

Table 3 shows the factor loadings on single factor and its Eigen value, percentage of variance and accumulative variance.

Table 3
Factor Loadings, Eigen Values, and Percentage of Variance on Single Factor of Perceived Barriers in Pursuing Engineering Scale (N= 324)

Items	Factor Loadings	Items	Factor Loadings
Barr1	.30	Barr14	.56
Barr2	.42	Barr15	.54
Barr3	.46	Barr16	.57
Barr4	.54	Barr17	.54
Barr5	.51	Barr18	.58
Barr6	.48	Barr19	.57
Barr7	.56	Barr20	.53
Barr8	.61	Barr21	.50
Barr9	.62	Barr22	.56
Barr10	.51	Barr23	.50
Barr11	.50	Barr24	.57
Barr12	.59	Barr25	.62
Barr13	.57	Barr26	.54
Eigen Value	7.76	Barr27	.52
Percentage of variance Explained	28.75		

Reliabilities

Cronbach alpha reliability of Perceived Barriers in Pursuing Engineering Scale is .90 with M = 77.29 and SD = 20.47. The reliability is above .80 which indicates high internal consistency of the score of scale (Schrepp, 2020).

Comparing Means (t-Test-Equal Variance Not Assumed)

Mean comparison of male and female students across barriers was established. The participants in each group was different so the readings considered in analysis was from the equal variance not assumed which is the same as Welch's t-test meant for unequal group mean comparison. The analysis reveals that boys perceive more barriers (M = 79.45, SD = 20.78) as compared to girls (M = 74.00, SD = 19.38) which is significant (t = 8.92, p < .05), 95% CI [.96-9.94] with a smaller effect size (.27).

Chi-square Analysis

Pearson chi-square test was conducted to examine the association between gender and response options for each item of the Perceived Barriers in Pursuing Engineering Scale. Male and female students were compared along the three response options: Low, Moderate, and High. The responses were merged for better understanding of the responses in terms of highly experienced to low experiences that is responses on *Very little/Not at all* and *A little* were merged as Low (perceived barriers); Moderate level of barrier was maintained as it is; while responses on *Quite a bit* and *Extremel*y in the Scale were merged as High (perceived barriers). The obtained differences have been presented in Table 4

Table 4

Frequencies and Chi-Square Results for Perceived Barriers in Pursuing Pre-Engineering and Gender (N = 324)

Item			Response						$\chi 2$ (2)	φ
			Low		Moderate		High			
			n	%	*n*	%	*n*	%		
1	Lack of supervision from the family									
		Male	**106**	52.7	36	17.9	59	29.3	13.49**	.20**
		Female	40	32.5	26	21.1	**57**	46.6		
2	Family pressures for certain field at the time of admission									
		Male	**107**	53.2	33	16.5	61	30.3	6.49*	.14*
		Female	**80**	65.04	21	17.1	22	17.8		
3	Lack of support from Family									
		Male	91	45.3	21	10.4	89	44.3	5.76	.13
		Female	72	58.5	11	8.9	40	32.5		
4	Lack of support from the teachers									
		Male	81	40.3	45	22.4	75	37.3	11.78**	.19**
		Female	**70**	56.9	12	9.7	41	33.3		
5	Lack of support from friends									
		Male	81	40.3	38	18.9	82	40.7	13.11**	.20*
		Female	**75**	60.9	16	7.9	32	26.01		
6	Lack of rules ensuring punctuality									
		Male	71	35.3	56	27.8	74	36.8	13.65**	.21**
		Female	**66**	53.6	33	26.8	24	19.5		
7	Ineffective teaching methods									
		Male	77	38.3	45	22.4	79	39.3	10.63**	.18**
		Female	**68**	55.3	26	21.2	29	23.6		
8	Lack or teacher's training									
		Male	81	40.2	34	16.9	86	42.7	11.11**	.19**
		Female	**73**	59.3	14	11.3	36	29.2		
9	Course content not covered completely by the teachers									
		Male	103	51.24	39	19.40	59	29.35	6.19*	.14*
		Female	**74**	60.2	28	22.7	21	17.1		
10	Poor time management by the teachers for covering course content									
		Male	100	49.8	38	18.9	63	31.3	4.68	.12
		Female	**71**	57.7	27	21.9	25	20.3		
11	Favoritism by the teachers									
		Male	70	34.8	59	29.3	72	35.8	3.89	.11
		Female	48	39.02	24	19.5	**51**	41.5		
12	Rote memorization/cramming system (no conceptual understanding)									
		Male	86	42.8	53	26.4	62	30.8	3.81	.11
		Female	**61**	49.6	21	17.1	41	33.3		
13	Curriculum not meeting the requirement of the field									
		Male	74	36.8	61	30.3	66	32.8	2.59	.09
		Female	**56**	45.5	30	24.4	37	30.1		
14	Less creativity, more spoon feeding									
		Male	**69**	34.3	49	24.4	**83**	41.3	12.41**	.19**
		Female	66	53.6	25	20.3	32	26.01		

15	Admission criteria at universities flawed									
		Male	64	25.8	44	21.8	**93**	46.2	1.08	.06
		Female	45	36.6	28	22.8	50	40.6		
16	Poor equipment/Lack of practical facility in schools/colleges									
		Male	87	43.3	40	19.9	74	36.8	1.18	.06
		Female	**58**	47.1	27	21.9	38	30.8		
17	Lack of ability for achieving high in pre-engineering									
		Male	73	36.3	45	22.4	83	41.2	10.14**	.18**
		Female	**62**	50.4	31	25.2	30	24.4		
18	Lack of career counseling in school/colleges									
		Male	77	38.3	43	21.4	81	40.3	6.42*	.14*
		Female	**64**	52.03	17	13.8	42	34.1		
19	Lack of interest of the students in field/subject									
		Male	69	34.3	44	35.8	**88**	43.7	7.24*	.15*
		Female	57	28.3	30	24.4	36	29.3		
20	Lack of scope of field									
		Male	84	41.8	46	22.9	71	35.3	1.02	.06
		Female	**54**	43.9	32	26.01	37	30.1		
21	Lack of information/ awareness about field of engineering among students									
		Male	78	38.8	43	21.4	80	39.8	2.31	.08
		Female	**58**	47.1	21	17.1	44	35.8		
22	Poor time management of the students									
		Male	72	35.8	48	23.9	81	40.2	1.22	.06
		Female	48	39.0	23	18.7	**52**	42.3		
23	Involvement/participation of students in non-academic activities									
		Male	**85**	42.3	46	22.9	70	34.8	2.66	.09
		Female	42	34.1	28	22.7	**53**	43.1		
24	Financial constraints									
		Male	63	31.3	72	35.8	66	32.8	12.32**	.19**
		Female	**60**	48.8	25	20.3	38	30.8		
25	Lack of confidence in one's abilities									
		Male	69	34.3	47	23.3	**83**	41.3	3.26	.10
		Female	49	39.8	35	28.4	39	31.7		
26	Overcrowded class									
		Male	78	38.8	45	22.4	76	37.8		
		Female	42	34.1	16	13.0	**65**	52.8	7.95*	.16*
27	Distracting class fellows									
		Male	78	38.8	41	20.4	82	40.8		
		Female	41	33.3	18	14.6	**64**	52.0	4.15	.13

* $p < .05$. ** $p < .01$. *** $p < .001$

Chi-square tests of independence revealed a significant association of gender and the first item with a very strong effect size. The pattern of the data indicated that the highest number of male students reported lack of supervision by parents to be the least encountered barrier by them, whereas, most female students indicated this to be a common barrier.

Another significance association for gender was observed in item 2 with moderate effect size. The highest proportion of male and female students reported least experience with the barrier of family pressures for certain field at the time of admission. The percentage of female students reporting low encounter with this barrier surpassed the percentage of male students.

Item 3, item 4, item 5 representing the barriers of lack of support from family, lack of support from teachers, and lack of support from friends, respectively, also possessed significant associations with gender. All these associations possessed moderate to high effect sizes as per phi-coefficients. Data suggests that the highest number of female students reported least encounter with all three of these barriers as compared to male students.

Item 6 representing the barrier, lack of rules ensuring punctuality, was another item possessing a significant association with gender with a very strong effect size. It was chosen as a least encountered barrier by the highest percentage of female students.

Coming to teacher related barriers, majority of female students chose item 7 that was ineffective teaching methods and lack of teacher's training as a least encountered barrier in comparison to male students. The majority of both the male and female students agreed that course content not covered completely by the teachers (item 9) was a least encountered barrier. Effect sizes of all these associations ranged from strong to very strong.

Gender was also associated with some environment related barriers. Female students expressed least encounter with the following barriers: less creativity, more spoon feeding (item 14) and lack of career counseling in school/colleges (item 18). Moderate to strong effect sizes were reported for these associations. However, overcrowded class (item 26) was the most encountered barrier by the majority of female students. This association had a strong effect size.

Some personal barriers that were associated with gender were represented by item 17, item 19, and item 24. Majority of female students reported least encounter with the barrier, lack of ability for achieving high in pre-engineering and financial constraints. As for the male students, their majority indicated most encounter with lack of interest of the students in field/subject. Strong to very strong effect sizes were reported for these relations.

In conclusion, large percentage of female respondents perceived less barriers than male counterparts. Male students specifically reported lack of supervision by parents to be a least encountered barrier. Whereas, female students reported least encounter with the following barriers: the barrier of family pressures for certain field at the time of admission, of lack of support from family, lack of support from teachers, lack of support from friends, lack of rules ensuring punctuality, ineffective teaching methods, lack of teacher's training, ineffective teaching methods, lack of teacher's training, less creativity, more spoon feeding, lack of career counseling in school/colleges, lack of ability for achieving high in pre-engineering, and financial constraints. Most encountered barrier by female student was lack of supervision by parents and

overcrowded class. Whereas, the only barrier encountered by most male students was lack of interest of the students in field/subject.

Discussion

Adolescent's stage is the most intense, instable, confused and difficult period of a person's life. He undergoes different hormonal changes which makes it difficult for him to endure minor stressors (Schweizer et al., 2020). They need support from the close circle and significant others to excel in their education and career.

In a developing country, like Pakistan the education system for engineering studies may not be as effective for satisfaction of the students and that may cause emotional distress, dissatisfaction, other negative emotions which may serve as major barriers in their education (Khan & Abid, 2021).

Students may not be interested in STEM fields but parents and significant others' influence the decision of a person pursuing education at FSc. Level for both males and females (Fisher et al., 2022) which may again be the reason for perceiving barriers in their education.

Gender biases/stereotyping (underrepresentation of females) is one of the main factor of interest for researchers in STEM related fields (Miner et al., 2019) for that matter the females might perceive more barriers in engineering education**.** This stereotypic threat to females undermined the attitudes and performances in STEM related subjects and losing the interest in the said fields.

Barriers related scales were available in the literature whose reliabilities and other psychometric properties were established (e.g., Hong et al., 2014 etc.) but they were used for different context for instance, in career persuasion, for physical disability, employment etc. or were validated for women, social sciences or general in nature. Hence, a need for developing an indigenous, contextual scale was observed and developed through rigorous literature search and FGD's with the concerned potential participants of the study.

FGDs are the most effective way for sequential exploratory research design for scale development (Cornely et al., 2022) hence, FGD's were conducted for the development of the Perceived Barrier Scale for Pursuing Engineering at FSc level.

FGDs were conducted with groups of students from Engineering in retrospection because they went through it and they better understand what lacking they felt in the previous year. Such experiences are recommended in the researches claiming that it provides fruitful information and side-by-side analysis of the previous and current scenarios than the current experience shared only (Lee et al., 2021). The students were from engineering so their perception of barriers was vast and they reported some barriers which were not related to the pre-engineering students. So, the scales were reviewed by pre-engineering teachers to select the most appropriate for pre-engineering students (at FSc level).

Barriers related to parents, teachers, students, academic administration, personal and financial etc. were reported. These barriers are also identified by previous researchers (e.g., Liebech-Lien, 2021etc.).

The identified and reviewed items by the teachers and experts were then compiled in the form of a 27 item scale with 5 response options and was administered on the FSc students for the validation purpose on 324 participants from pre-engineering. Factor analysis was done using Principal Component Analysis. Exploratory factor analysis was run first to identify the factor structure and currently, Oblique rotation using Direct Oblimin method with Principal Component Analysis for the extraction of meaningful factors in the scale was used (Bugajski et al., 2019), which is better in social sciences as latent variables cannot be uncorrelated and are correlated to some extent. Principle Component Analysis is widely used though it is not a factor analysis technique in true sense. It is a data reduction technique (Bandalos & Finney, 2018). Other researchers have also used the same method for factors extraction through EFA (see Taherdoost et al., 2022). Initially 4 factors were extracted and expert reviews suggested 3 factors as some items were representatives of the three extracted factors. So, a 3 factor extraction was performed and the values were all intact and extractions were meaningful statistically.

A review committee was again involved as the factors were not theoretically intact with the factors they were loading on. So, factors were extracted limiting to 2-factors, then 5-factors then EFA was performed not limiting the factors and it was observed that the loadings are majorly on one factor indicating the unidimensionality of the scale. Hence, a unidimensional scale was finally retained keeping in view the theoretical coherence of the scale.

The barriers were related to support issues from the significant others and the incompetence of the teaching faculty. These barriers identified in the scale were also identified in the previous literature as the major contributors to the satisfaction, persuasion and satisfaction of the students (e.g., Kaimara et al., 2021). Some of the items were related to the academic support, the content, academic system, facilities at the laboratory and supervision from the academia. These issues had an evidence in previous literature too with the pre-engineering level (see Afsar & Jami, 2020). Some items were related to different aspects including many of the personal factors like ability, time management, competence etc. Personal factors were also revealed in the previous literature (e.g., Afsar & Jami, 2020).

As explained earlier, there were a lot of different barriers identified from the FGDs and the literature search but all of them were rated differently in the quantitative part of the study. Some of the factors were agreed to more than the others as explained in Table 4 in result section. The reason for the under-representation of certain barriers may be that the students may not be realizing that these hindrances are bothering their educational career, they may not be regularly attending their institutes as the punctuality rules were not implied which was confirmed from the teachers and administrators as well but in the quantitative study it was not highlighted.

The other reasons may be that they have joined academies or tuitions where the content is covered, their teachers put a lot of efforts to make them understand the concepts so they did not mention these issues in their pre-engineering level. The lack of awareness may also be the reason. Because this is the major discrepancy in the qualitative and quantitative study of the same research and also from the previous literature.

The perception of barriers is different as the participants differ. It is advisable to administer this scale on various data to see how the perception of barriers changes from one group to another as it changed from qualitative phase to the validation phase in the same research findings.

Literature suggested that teachers' lack of qualification may lead to low quality teaching method in teaching the dynamics of such important fields (Ritz & Fan, 2015) which was also in the result of focus group discussion but then this aspect was minimally reported in the data sets.

The dilemma of how, when, and by whom to guide, teach and explore the technological fields and prepare the students at school level for technological domains has not yet been solved. Although efforts have been made in identifying the factors affecting interest in STEM fields. The same was concluded in the present study and the interest factor was more prominent to be lacking in the students and specially the information about the field which was common in both phases (qualitative and validation study).

The reliability of the scale ($N = 324$) was above .80 which is very satisfactory and the item total correlations ranges from $r = .35$ to $r = .61$ ($p < 0.01$). So, the items were all positively significant.

Gender differences has been reported throughout the literature specially in engineering related field and overall STEM education. Although females are underrepresented in the engineering field, the reason for which was lower self-efficacy of the females.

Our study revealed that females perceive less barriers than males in engineering education. Which implies that the self-efficacy is their main barrier not the course of persuasion in engineering fields. These results were significant. This was not assumed in the study. There might be various reasons for perceiving lower barriers by girls than boys. This may be due to societal expectations the Pakistani educational system (Kanwal, 2023), parental guidance (Manzano-Sanchez et al., 2019), cultural factors (Yasmin, 2020), role models (González-Pérez, et al., 2020), shifting gender dynamics (Block et al., 2019), advocacy for gender equality (Nash et al., 2021), the intersectionality of gender with other variables such as socioeconomic status, race, and cultural background (Tao & Leggon, 2021).

The Pakistani educational system's curriculum (Yasmin et al., 2020), instructional approaches, and vocational counseling (Kanwal, 2023) may inadvertently discourage male students from pursuing a career in engineering. Parents' expectations (Rasool et al., 2020) and encouragement (Hussain et al., 2020) play a significant role in shaping a child's career choices. Cultural factors, such as Pakistan's diverse nation, also play a role in shaping perceptions of barriers. The presence of male engineering role models may result in boys perceiving increased barriers. The global trend towards gender equality has the potential to increase the perception of barriers among boys, as they may experience heightened pressure to excel in traditional male-dominated fields.

The data of females versus males were highly different so it was suggested to use the values of equal variance not assumed in the t-test result table or use Welch test in one-way ANOVA which gives the same results (Cavus & Yazici, 2020). So, we applied *t*-test and considered values for equal variance not assumed.

In summary, the results indicate that boys exhibit a greater perception of barriers hindering their pursuit of engineering compared to girls. These findings challenge prevailing assumptions in this field. The findings presented in this study present a valuable opportunity to further investigate the fundamental factors that contribute to these perceptions, as well as to formulate effective strategies aimed at promoting increased inclusivity and equality in STEM disciplines, irrespective of gender. Additional investigation regarding this subject matter can contribute to a deeper understanding of the intricate dynamics involved.

Limitations and Suggestions

Scales for barriers were already available in the literature but contextually developed indigenous scale was much needed for the pre-engineering students specifically. The most important suggestion is to use this scale with pre-engineering students and do the confirmatory factor analysis on acquired data for future confirmation of the scale to be used effectively.

Use of variable (barrier) is suggested to be used with other variables to check the relationships, gender differences and other influences of barrier on other important variables.

The barriers perceived may be different in groups having different achievement levels so it is also suggestable to use the scale on high and low achievers to know the exact differences among the groups. At FSc Level there are two years of education (i.e., first year and second year) and their perceived barriers may also differ.

The students who studied from the same school over a few years and the fresh students coming/migrated from other schools or colleges may perceive barriers differently. So, this aspect can also be covered which will provide more clarity to the scenarios in terms of barriers perceived.

Cross-cultural evidences may also be helpful in understanding the differences prevailing in perception of barriers. So, it is highly recommended to be used in different cultures to know the cultural variation with in the country as well as across the country.

Implications

Barriers are among the most important consideration in engineering related fields and it vary across fields, level of education, career paths, areas of specialization, disabilities, minorities, geographical location and many more. So, developing a scale that covers a specific educational level and targeting a specific group of students will be very effective in understanding point of views of the students and stakeholders. Also, it may help future researchers to identify barriers using this scale and find out what particular results they get.

For the stakeholders it will be very important to identify the highest reported barriers and bring them down to the optimal level to help students succeed in their field and score better grades in their educational career.

Every country around the world is in dismay because of the scarcity of effective engineers in the world. This a very drastic situation for the technological era and needs to be rectified effectively. This research may help them understand at least the commonly perceived barriers in the engineering education.

The government can help in schemes and opportunities for the teacher's training, availability of the effective resources, personality grooming, awareness campaigns and information dissemination among the potential engineers which were identified to be the major barriers perceived.

Counseling of the parents and students may be helpful as suggested by this research and it can overcome many indifferences among the parents and teachers.

Pakistan is a developing country, we need to compete with the increasing standards and demands of the world and progress in the technology for which engineering education will play the most important role. Facing barriers may hinder and retard the growth of this field and thinking abilities of the students too. They will be directing their efforts in overcoming the barriers instead of excelling in the field which could be very unfortunate for the future of Pakistan as well as the future of technological growth.

Conclusion

From the present study, we conclude that Perceived Barriers in Pursuing Pre-Engineering Scale is a valid and reliable measure to identify barriers in the pre-engineering students. We can also conclude that barriers perceived are different in male and female students studying at pre-engineering level.

Declaration

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Conflict of Interest.

The authors did not declare any conflicts of interest.

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Availability of data and materials.

Information about dataset and analyses for present study is available from corresponding authors.

Ethical.

Research was approved by the institutional ethical board.

Competing interests.

The authors did not declare any competing interests.

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