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Influences on Freshman Attitudes toward Engineering: Lessons from a Case Study of a Major Engineering University in Pakistan*

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This 'evidence based practice paper' reports influences on freshman attitudes toward engineering at a major engineering university (MEU) in Pakistan. The assessment is based on surveys conducted with incoming MEU students before and after their participation in a one-credit engineering education foundation course (EGR 100). This course is designed to make students passionate about engineering, enable them to become active learners, and prepare them to undertake the rigors of an engineering curriculum. Attitude data was collected at the beginning and toward the end of the course, using a modified version of the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS). Additional items recorded student demographics. Analyses in the paper include pre and post course comparisons of 718 students who completed both the pre and post course surveys. The paper also considers the impact of gender and type of secondary education. The paper concludes with a discussion of the implications of our findings for engineering education at MEU and other engineering programs.

Keywords: engineering attitudes; freshman engineering; active learner; PFEAS

1. Introduction

Finding useful means to attract and retain engineering majors is of perpetual interest to engineering institutes/schools and faculty. This study is an evidence based assessment of freshman attitudes toward engineering at a Major Engineering University (MEU) in Pakistan. The analysis is based on the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS), which is a useful and popular instrument in engineering education for measuring freshman attitudes towards engineering and their confidence in their abilities to perform as engineering students. PFEAS has previously been used in a number of similar studies [1–4]. The assessment is based on surveys conducted with incoming MEU students before and after their participation in a one-credit engineering education foundation course (EGR 100). This course is designed to enhance students' passion for engineering, transform them into active learners, and to mentally prepare them for a four year engineering program.

The paper begins with a discussion of the primary and secondary education systems in Pakistan and the significance of gender for education in Pakistan as a means to better understand the context for engineering education in the country. A short review of engineering education in Pakistan is then provided along with a description of the MEU engineering foundation course. After discussing details regarding the data and methods used in the analysis, the findings of the study are presented. These findings address two research questions: (1) is there a significant change in student attitudes and beliefs about engineering as a result of the EGR 100 Course? And (2) is there a significant impact of gender and/or type of secondary school on student attitudes toward engineering? The paper concludes with an interpretation of the findings and their implications for engineering education at MEU and other engineering programs, along with a discussion of the limitations of this research.

2. Education in Pakistan

2.1 *Organization of basic education*

Since her independence in 1947, Pakistan has struggled to establish a high quality, standardized education system. This, in turn, has been one of the main impediments to the nation's economic and social development [5, 6]. This situation is further aggravated due to an alarming rate of population growth: Pakistan's population is currently estimated to be over 190 million, making it the sixth

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largest nation in the world, with a median age of 21.6 years and with 35% of the population aged 15 or younger [7–9]. Despite recent encouraging measures taken in the higher education sector with the establishment of the Higher Education Commission (HEC) in 2002 (for instance, offering indigenous as well as international fully funded scholarships in all disciplines for MS and PhD degrees, International Research Support Initiative Program, i.e., sending researchers abroad, who are pursuing their PhD in Pakistan, to any institution of repute for six months to enhance the quality of their research, introducing best teacher and best researcher awards at national level, etc.), there are numerous issues faced by the Pakistani basic education system (primary and secondary education or K-12) in its quality, accessibility and equality of opportunities [10]. A significant barrier to reform has been that successive national governments have failed to develop a basic educational infrastructure that provides a free, quality education to the children. This has led to the proliferation of a variety of private schooling systems following local, British, or US standards and curricula.

The basic education system in Pakistan may be divided into four levels: (1) primary (grades 1–5); (2) middle (grades 6–8); (3) secondary (grades 9–10); and (4) higher secondary (grades 11–12). Approximately 80% of Pakistani children finish primary school education [7–9]. The standard national system of education is based on the British system, typically with co-education in grades 1–5. After this, single-sex education is typical, though co-education is also common in urban cities. In primary education, the curriculum is usually determined at the school level. The eight commonly examined disciplines are Urdu, English, mathematics, arts, science, social studies, Islamic studies (for Muslims)/ethics (for non-Muslims) and computer studies. Provincial and regional languages such as Punjabi, Sindhi, Pushto, Baluchi and others are also taught in their respective provinces. Urdu is the national language of Pakistan; however, English is used as the medium of instructions especially for the teaching of science and mathematics beginning with the primary level.

Middle (especially for grade 8) and secondary education in Pakistan is regulated by a regional Education Commission and Board of Intermediate and Secondary Education (BISE). Upon completion of grade 8, students are expected to take a standardized test and on successful completion they are awarded a Middle Pass Certificate from their respective Education Commission.[1] Similarly, upon completion of grade 9, students are expected to take a standardized test on the first half of each of their academic subjects. They again take tests on the second half of the same courses at the end of grade 10. Upon successful completion of these two examinations, they are awarded a Secondary School Certificate (SSC). Students then enter an intermediate college and complete grades 11 and 12 in one of four streams: pre-medical, pre-engineering, general science, or humanities (including social sciences) and commerce. Upon completion of each of the two grades, they again take standardized tests in their academic subjects and upon successful completion are awarded the Higher Secondary School Certificate (HSSC). For pre-medical and pre-engineering streams, this level of education is also called the Faculty of Science (FSc.).

Though each has its own strengths, the variety of basic education systems in Pakistan[2] produces a varied and non-standardized pool of potential students for admission to the higher education system. As a result, universities face a degree of uncertainty in the selection and admission procedures, thus potentially putting applicant groups from particular school types at a serious disadvantage. The situation is further aggravated when other student demographics, in particular gender, are considered.

2.2 *Gender and education*

Gender differences in school enrollment run throughout the education system in Pakistan. For boys, the primary school net enrollment rate is 79.0% and the attendance rate is 70.0%, while for girls the net enrollment rate and attendance rate is 65.0% and 62.3% respectively [12]. Net enrollment rates drop at the secondary school level to 34.6% for boys and 28.9% for girls.[3] Moreover, there are large

[1] Private schools, however, have flexibility with regard to regulation, that is, they may or may not be part of the respective provincial Education Commission and can conduct the examination at the school level.

[2] The most common alternative to the local education system is the General Certificate of Education (GCE), where SSC and HSSC are replaced by Ordinary level (O levels) and Advanced level (A levels) respectively. Other qualifications include IGCSE which replaces the SSC. GCE O levels, IGCSE and GCE A levels are managed by British examination boards of CIE (Cambridge International Examinations) and/or Edexcel of the Pearson PLC. Generally, 8–10 courses are selected by students at GCE O levels and 3–5 at GCE A levels. Advanced Placement (AP) is an alternative option but much less common than the GCE or IGCSE. The AP replaces the secondary school education as 'High School Education'. AP exams are monitored by a North American examination board, the College Board, and can only be given under the supervision of centers that are registered with the College Board, unlike GCE O/A levels and IGCSE, which can also be given privately. Private schools in Pakistan, which have been expanding relatively rapidly, promote GCE O/A level education system in the urban areas of the country. Since 1979 there has been a significant and continuous growth in the number of children with GCE O/A level qualifications with a nearly tenfold increase from 1983 to 2000 [11].

[3] It is worth mentioning that any statistics provided about education rates in Pakistan may be questionable, as some sources report that on any given day across the country about 13% of the teachers and 18% of the students are absent [13].

gender gaps in learning outcomes, with boys outperforming girls across all grades in both reading and math skills, especially in rural and remote regions, particularly in the northern areas of the country [14]. The most disadvantaged groups, when it comes to equal opportunities to enroll in and complete school, are found at the intersection of gender and other sources of marginalization. Such intersections include combinations of being female, poor, disabled, belonging to a linguistic, religious, or cultural minority, and living in a rural area [15].

Currently only 5.1% of Pakistan's youth aged 17–23 are enrolled in higher education, despite the fact that higher education enrollment in Pakistan has grown dramatically in the past 15 years [16]. In 2001 there were only 276,270 students enrolled in higher education and 37% were females. By contrast, from 2006 to 2010 overall enrollment grew from 521,473 to 948,268 and during this time female enrollment in higher education increased markedly as well, from 41% to 45% [17]. By comparison, overall female enrollment at the MEU studied in this paper was only 23% in 2015. For the purposes at hand, it is important to note that this gender disparity is most acute in the engineering disciplines, where only 13% of the students are female. This percentage climbs to 39% for the natural sciences and 44% in the business school. On the other hand, at MEU 63% of the students in the social sciences, 81% of those in art and design and 87% in the applied biosciences are female.[4]

2.3 Engineering education

Pakistan is a provisional member of the Washington Accord and all its undergraduate engineering programs are conducted on a standard 4-year curriculum with a minimum of 128 credit hours [18]. Students are enrolled discipline-wise to a degree on the basis of students' discipline preferences, but primarily on merit based on their performance in the SSC, the HSSC, and an admission (or entry) test similar to the American SAT. Admission tests unlike SAT are not standardized; these are generally specific and conducted by the respective universities at different schedules of their choosing thus putting an extra burden (both mental and financial) on students and parents. Adding to this burden, private academies/tutoring centers have mushroomed in the country (as a result of specific entry test requirement of each university) claiming to prepare the candidate for each entry test.

The engineering curriculum in the first two years of the engineering programs is common, however, the programs are still structured with little flexibility available to students to switch to other disciplines (within and outside engineering) after their initial enrollment or to make any significant changes in subject selection. All engineering programs are regulated by the Pakistan Engineering Council (PEC), a statutory accreditation body constituted under an Act of the Pakistani Parliament (PEC Act 1976) [18]. English is used as the means of formal communication and medium of instruction in higher education.

In line with current research practices and the needs of the existing education environment, a study was conducted at a MEU in Pakistan to identify initial attitudes of freshmen as they join the engineering program and examine changes in these attitudes after their participation in a one-credit (16 contact hours) engineering foundation course (EGR 100). This course is conducted for one week, prior to the beginning of the engineering program. The MEU offers undergraduate engineering programs in thirteen disciplines with a yearly intake of approximately 2,000 freshmen selected from an average of 30,000 applicants from across the entire country on the basis of a computerized merit-based admission system. EGR 100 was first piloted in the summer of 2014. After a trial development period, during which the course was offered as an optional course, it was integrated into the freshman curriculum (still as an optional course) beginning in the fall of 2014. From the fall of 2014 and onwards students are enrolled in EGR 100 according to the wishes of individual MEU constituent colleges.

3. The MEU EGR 100 engineering foundation course

3.1 The approach

Previous research indicates that student initial attitudes and changes in attitudes toward engineering during the freshman year play a significant role in their motivation, performance, and retention in engineering programs [19, 20]. A longitudinal study of several institutions found that students who chose engineering majors and graduated as engineers held positive perceptions toward engineering. On the other hand, students who did not choose engineering majors or dropped out from engineering programs had a negative impression of engineering, lacked confidence in their abilities to complete the engineering program and had little or no motivation for studying science and mathematics [21]. Student attitudes therefore can provide an effective means for assessing and evaluating the potential of engineering programs to graduate quality engineers. In that context, several renowned engineering institutions have introduced measures to significantly improve student attitudes toward

[4] Information on enrollment according to gender was obtained directly from the MEU Registrar's Office in January 2016.

engineering. These measures include but are not limited to: treating first year as a common freshman year to be handled by a separate school/department of engineering education research, and, introducing cornerstone courses (freshman design sequences) to improve their attitudes toward engineering. Such measures have significantly improved student performance and retention [22–24].

3.2 The EGR 100 course

EGR 100 is a cornerstone course that has been specifically designed for freshman engineering students in Pakistan, within its existing socioeconomic environment, to address the inadequacies of the primary/secondary education system of Pakistan and specifically to promote the following objectives: (1) to boost passion for engineering; (2) to fuel subject specific curiosity; (3) to enhance self-confidence and self-esteem; (4) to link academics with real life; (5) to revisit foundational and basic science concepts; (6) to enable students to realize and connect with their own tacit knowledge (in everyday language); (7) to activate thinking processes; and, (8) to encourage them to develop a holistic approach to problem solving beyond text book solutions. Overall, the curriculum of EGR 100 was designed to achieve cyclic integration of the *student* with *engineering* and *education* (see Fig. 1).

In the course students are given a broad but comprehensive preview of engineering and engineers in order to instill passion in them for the profession. They are then exposed to educational methods and techniques of acquiring knowledge to make them capable of transforming into active learners[5] [25, 26]. The course reconfigures their mindset and enables them to exploit their strengths and overcome their weaknesses. In short, EGR 100 seeks to install a Mind Operating System (MOS) in freshmen that establish new ways to interface their physiology with psychology thus enabling them to undertake the engineering program in a fearless and self-assured manner.

The objectives set forth for the course are achieved through the application of intervention tools and techniques that are designed to work in unison. The course lectures are delivered in a seminar or workshop manner using andragogic techniques rather than pedagogic techniques. The latter are typically employed in engineering education in Pakistan [27]. With the former the instructor acti-

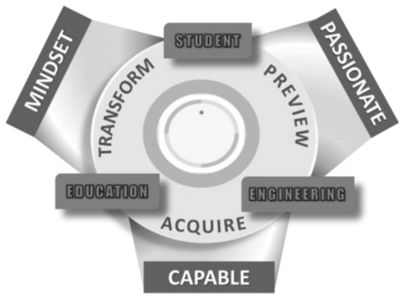

Fig. 1. Cyclic integration of student with engineering and education.

vates the student's prior or tacit knowledge and links it with content knowledge, thus opening a new perspective on *learning with understanding* [28]. Abstractions are minimized by using analogies. The need for various skills, different techniques, correct attitudes and right approaches to learning and pursuing engineering education are emphasized. In short, the student is provided a holistic view of the rapidly changing global engineering profession by appreciating the importance of teamwork, project management, innovation, hands-on experience, ethics, career preparation and professionalism to affect an appreciable and positive change in freshman attitudes toward engineering. The goal is for students to improve self-esteem, to learn techniques to overcome anxiety, emotions, and to gain practice with intellectual tools and ways to develop an engineering mindset [25]. An outline of course curriculum and intervention tools and techniques used in EGR 100 is given in Appendix A.

4. The MEU EGR 100 study

4.1 Research question

This study seeks to better understand the effects of the cornerstone engineering foundation course (EGR 100) on freshman attitudes and beliefs about engineering and to establish the extent to which the course is meeting its defined goals. Simply put, whether or not the course is successful is the empirical question this research seeks to answer. The study performs a direct comparison of student attitudes captured in the beginning and toward the end of course. Those who took the course formed the treatment group to set the stage to examine the key research question for this study:

1. *Is there a significant change in student attitudes and beliefs about engineering in the beginning and toward the end of the EGR 100 Engineering Foundation Course?*

In the context of intervening effects, a secondary research question emerges:

[5] We define an *active learner* as a self-assured, fully motivated and optimistic individual, who recognizes that learning is a perpetual attainable requirement of life and is primarily an individual's responsibility warranting him/her to play an active role to acquire knowledge through any source, applying all possible means, methods and techniques by committing one's own potentials, skills and abilities.

2. *Is there a significant effect of gender and/or type of school system on student attitudes toward engineering?*

4.1.1 Null hypotheses-1

Freshman attitudes do not change over time during the course of EGR 100.

$$H_{01} : \mu_{pre} = \mu_{post} \quad (1)$$

Where,

$\mu_{pre} \equiv$ population mean at pre-course, and,
$\mu_{post} \equiv$ population mean at post-course.

4.1.2 Null hypotheses-2

Gender and type of secondary school system attended do not affect student attitudes toward engineering at the beginning and toward the end of EGR 100 or the manner in which those attitudes change between the beginning and end of the course.

$$H_{02a} : \mu_{pre/male} = \mu_{pre/female} \quad (2)$$
$$H_{02b} : \mu_{post/male} = \mu_{post/female} \quad (3)$$
$$H_{02c} : \mu_{pre/FSc\ Level} = \mu_{pre/OA\ Level} \quad (4)$$
$$H_{02d} : \mu_{post/FSc\ Level} = \mu_{post/OA\ Level} \quad (5)$$
$$H_{02e} : \beta_{gender} = 0 \quad (6)$$
$$H_{02f} : \beta_{school\ type} = 0 \quad (7)$$

We use "paired samples t-tests" to provide the statistical tests for Hypothesis-1, "independent samples t-tests" for Hypotheses 2a through 2d and "lag regression models" to provide the tests for Hypotheses 2e and 2f [29–33]. In models (6) and (7) we test whether the unstandardized regression coefficients are equal to zero as represented below in the estimation equations (8) and (9) by "b_2 Gender" and "b_2 SchoolType" respectively.

5. Data and methods

To measure the impact of the EGR 100 course a literature search was undertaken for valid and reliable survey instruments that could assess the attitudes and beliefs among student cohorts and, particularly, how they are impacted by cornerstone courses. The Pittsburgh Freshman Engineering Attitude Survey (PFEAS) was found to be the most relevant because: (1) it was originally developed for a similar study; (2) student attitudes were measured by grouping the items under thirteen measures or factors, most of which were of interest to this study; (3) it had been extensively used by various institutions and cited in a number of refereed publications [1–4]; and (4) it had an established high degree of validity and reliability [21]. The instrument is designed to measure student attitudes in four dimensions: (1) student definition of engineering; (2) student attitude about engineering; (3) student self-assessed confidence; and, (4) student self-assessed skills. The survey items are rated on either a five point Likert scale or an ordinal-based self-assessed confidence scale. The items statistically cluster into thirteen sub-scales, as listed in Table 1. These sub-scales define distinct domains of the instrument's main construct, i.e., freshman attitudes toward engineering. Items that are included in multiple subscales (e.g., self-reported confidence in the subject of chemistry is part of the BASIC subscale as well as the CONFIDENCE subscale) are only included once in the overall COMBINED scale. A copy of the survey with the wording for each item is found in Appendix B.

Additional items in the pre and post course surveys recorded students' demographic and socio-economic characteristics. Students in four constituent schools of the MEU in three semesters (fall 2014, summer 2015 and fall 2015) were sur-

Table 1. Defining the PFEAS sub-scales.

No.	PFEAS Items	Subscale Name	Definition of Subscale
1.	1-3, 4*, 5, 6*, 7, 8*, 9*	CAREER	General impression of engineering
2.	10, 11, 12, 13	JOBS	Financial influences for studying engineering
3.	14, 15	SOCIETY	How engineers contribute to society
4.	16, 17, 18, 19, 20, 49, 50	PERCEPTION	Work engineers do and engineering profession
5.	21, 22*	MATH	Enjoyment of math and science
6.	23, 24	EXACT	Engineering perceived as exact science
7.	25, 26	FAMILY	Family influence to studying engineering
8.	27, 28, 29, 30, 37	BASIC	Confidence in basic engineering knowledge & skills
9.	35, 36, 37	COMMUNICATION	Confidence in communication and computer skills
10.	38*,39	STUDY	Adequate study habits
11.	40, 42*,43*	GROUPS	Working in groups
12.	31, 45, 46, 47, 48	ABILITY	Problem solving abilities
13.	32, 33, 34, 44	COMPATIBILITY	Engineering abilities
14.	27–37	CONFIDENCE@	Overall confidence in abilities and skills.
15.	All of the above items	COMBINED@	Overall attitude toward engineering.

*Reverse scored items. @ Not part of original PFEAS subscales.

veyed. A total of 912 pre course surveys and 859 post course surveys were completed. Analyses in this paper compare pre and post course cross-sectional measures, as well as individual-level longitudinal analyses, for 718 participants who submitted both pre and post course surveys and completed one or more items in each of the survey subscales. A comparison of entrance examination scores for students who took EGR 100 in the fall of 2014 compared to other students entering engineering programs in that semester found no statistical difference between the two groups ($t = 1.436$, $p = 0.152$, $N = 1{,}362$). We also did not find a statistically significant difference between the two groups in their grade point averages (GPAs) after their first semester at MEU ($t = 0.964$, $p= 0.335$, $N = 1{,}770$).

6. Findings

The analyses presented in this paper focus on changes in the overall attitude scores made up of a combination of items found in all subscales, the individual subscales, and how changes in the overall scale and subscales vary with gender and secondary school type.

6.1 Descriptive results

In the longitudinal sample of 718 students with complete pre and post test measures the mean engineering attitude scale COMBINED increased from 3.65 to 3.70 from the beginning to the end of the five day EGR 100 course. As Fig. 2 shows scores for both the pre and post surveys were normally distributed. As expected, the individual-level values for the overall pre and post measures were correlated with a moderately strong, and statistically significant Pearson correlation coefficient ($r = 0.578$, $p < 0.001$).

As noted above, along with the change in the COMBINED engineering attitude scale and its subscales between the beginning and end of the course, the analysis in this paper focuses on variation in this scale and its subscales according to gender and type of secondary education. The cases used in the analyses presented included 83.7% male students and 16.3% female students. The majority of students, 82.0%, attended FSc schools prior to entering the university, while 12.1% attended O/A level schools, 0.8% attended other types of schools and 5.0% failed to provide information on the type of secondary school attended. Our analyses of the overall scale and its subscales according to type of secondary school will focus on students from FSc and O/A level schools and exclude the other 5.8% of respondents who attended other types of schools or did not indicate the type of school attended.

6.2 Changes in engineering attitude scale and subscales

Table 2 provides values for paired t-tests comparing pre, column (1), and post, column (2), course scores of all participants for the overall COMBINED scale as well as each of the subscales. Column (3) shows paired t-test values comparing individuals' pre- and post-course scores. Positive values indicate increases in scores between the beginning and the end of the course. Those differences that are statistically significant are flagged with one asterisks ($p < 0.05$) or two asterisks ($p < 0.01$). Column (4) shows the substantive significance (effect size) using Cohen's d.

As indicated in Table 2 the change in the overall engineering attitude scale (COMBINED) from the beginning to the end of the course, from 3.65 to 3.70 was highly statistically significant ($t = 4.41$, $p < 0.001$). Moreover, statistically significant increases were found in ten of the scale's fourteen subscales (JOBS, SOCIETY, PERCEPTION, MATH, BASIC, COMMU-

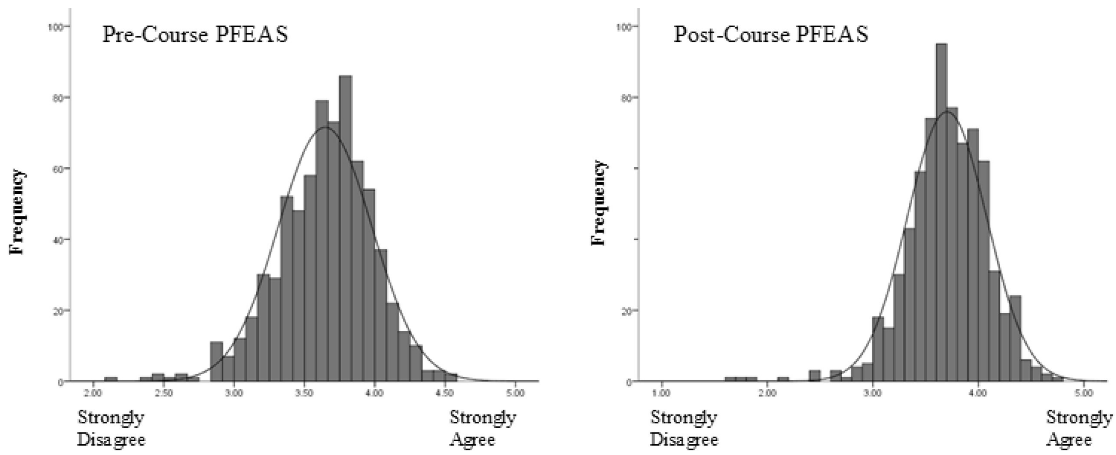

Fig. 2. Distribution of pre- and post- course COMBINED scores on the PFEAS.

Table 2. Pre-, post- course means and differences in PFEAS COMBINED scale and subscale scores

PFEAS Subscale	Pre-course mean (1)	Post-course mean (2)	Paired t-test values (3)	Effect Size Cohen's d (4)
COMBINED	3.65	3.70	4.41**	0.17
CAREER	3.98	4.01	1.35	
JOBS	3.09	3.17	2.63**	0.10
SOCIETY	3.84	3.91	2.01*	0.08
PERCEPTION	4.20	4.25	2.43*	0.09
MATH	3.81	3.88	2.11*	0.08
EXACT	3.80	3.80	0.09	
FAMILY	2.86	2.90	1.03	
BASIC	3.66	3.76	3.42**	0.13
COMMUNICATION	3.47	3.53	2.65**	0.10
STUDY	2.57	2.49	–2.89**	0.11
GROUPS	3.09	3.15	2.00**	0.07
ABILITY	3.78	3.86	3.51**	0.13
COMPATIBILITY	3.48	3.62	5.31**	0.20
CONFIDENCE	3.59	3.67	4.58**	0.17

NICATION, GROUPS, ABILITY, COMPATIBILITY, CONFIDENCE). In one instance (STUDY) there was a significant decrease in the score from the beginning to the end of the course. No significant difference was noted with the remaining three subscales (CAREER, EXACT, FAMILY). Moreover, for the scales having significant differences in their pre and post scores, the effect size has been calculated using Cohen's d statistic [34] and the results are illustrated in Table 2. These results show a small effect size since the calculated values of d statistics are less than or equal to 0.20.

6.3 Change in engineering attitude subscales according to gender

Table 3 summarizes differences in pre and post attitudes according to gender and how overall and subscale scores changed between the beginning and end of EGR 100. Column (1) shows no statistical evidence of an overall (COMBINED) difference in the engineering attitude scale. However, there are statistically significant differences in three subscales: female participants scored higher on the CAREER and SOCIETY subscales, while male participants scored higher on the FAMILY subscale. Column (3) shows that at the end of the course, however, female participants score significantly higher on the overall scale than male participants, as well as in three specific subscales: as before in CAREER, SOCIETY, but now also in PERCEPTION. In the post course measure, there is no longer a significant difference in FAMILY according to gender. For the subscales showing statistically significant difference in their scores, both pre and post scenarios, the effect size has also been calculated and found to be between 0.20 to 0.40 suggesting a small to medium effect size.

Column (5) of Table 3 presents results from a lagged ordinary least squares (OLS) regression model where gender differences in the end of course attitude scale and subscales are captured, controlling for attitude scale responses at the start of the course. This model may be represented as:

Table 3. Pre-and post-course t-test values[1] for differences in means by gender and unstandardized OLS lagged regression model coefficients[2]

PFEAS Subscale	t-test value Pre-course (1)	Pre-course Effect Size[3] (2)	t-test value Post-course (3)	Post-course Effect Size[3] (4)	Unstandardized Coefficients (5)
COMBINED	0.78	0.08	2.51*	0.26	0.078*
CAREER	3.15**	0.33	3.81**	0.40	0.126**
JOBS	–0.170		1.36		0.103
SOCIETY	2.05*	0.21	2.62**	0.27	0.162
PERCEPTION	1.79	0.18	3.05**	0.32	0.121*
MATH	0.45		1.35		0.092
EXACT	0.78		1.21		0.065
FAMILY	–2.49*	0.25	–0.46	0.05	0.115
BASIC	–1.68		–0.76		–0.009
COMMUNICATION	0.76		1.20		0.055
STUDY	0.61		–0.10		–0.030
GROUPS	–1.01		0.78		0.119
ABILITY	–0.71		0.41		0.052
COMPATIBILITY	–1.23		–0.54		0.009
CONFIDENCE	–0.70		0.40		0.046

[1] Positive value indicates higher values for females; [2] males are the reference group, positive coefficients indicate greater pre- post course changes for females.; [3] Effect size uses *Cohen's d*.

Table 4. Pre-and post-course t-test values[1] for differences in means by type of secondary school and unstandardized OLS lagged regression model coefficients[2]

PFEAS Subscale	t-test value Pre-course (1)	Pre-course Effect Size[3] (2)	t-test value Post-course (3)	Post-course Effect Size[3] (4)	Unstandardized Coefficients (5)
COMBINED SCALE	–0.22		–0.01		0.005
CAREER	–0.63		–0.34		–0.002
JOBS	1.77	0.21	2.23*	0.26	0.117
SOCIETY	4.91**	0.57	3.67**	0.40	0.159
PERCEPTION	–0.24		–0.53		–0.026
MATH	–0.42		–0.81		–0.056
EXACT	0.44	0.05	2.01*	0.23	0.153*
FAMILY	0.18		1.06		0.109
BASIC	–2.72**	0.32	–1.05	0.14	0.006
COMMUNICATION	–3.55**	0.34	–2.91**	0.33	–0.059
STUDY	0.71		0.31		–0.002
GROUPS	1.58		1.67		0.090
ABILITY	–1.38		–1.21		–0.030
COMPATIBILITY	–0.40		–1.25		–0.086
CONFIDENCE	–2.56**	0.30	–2.53*	0.29	–0.059

[1] positive values indicate higher values for students for FSc secondary schools; [2] students from O/A level schools are the reference group, positive coefficients indicate greater pre- post course changes for students from FSc secondary schools; [3] Effect size uses *Cohen's d*.

$$PFEAS_{Post} = a + b_1\ PFEAS_{Pre} + b_2\ Gender \quad \text{(where: male = 0, female = 1)} \qquad (8)$$

These results indicate that the increase in the overall engineering attitude scale between the pre and post measures, as noted in Table 2, was significantly greater for female than for male participants. Further, the statistically significant increase in the CAREER and PERCEPTION subscales found in Table 2 was significantly greater for females than males.

6.4 Change in engineering attitude subscales according to type of secondary education

Table 4 represents changes in COMBINED and subscale scores from the beginning to the end of the course broken down by whether or not participants attended O/A level or FSc secondary schooling. In column (1) we see that while there is no difference in the pre course overall scale measure according to type of school, participants from FSc schools scored significantly higher on the SOCIETY subscale, while participants from O/A level schools scored significantly higher on the BASIC, COMMUNICATION and CONFIDENCE subscales. Column (3) of Table 4 shows that there is also no difference in the overall COMBINED engineering attitude scale according to school type at the end of the course. With regard to the subscales in the post measures, the significantly higher pre course scores for FSc participants in the SOCIETY subscale remain in evidence. In addition, participants from FSc schools now also score significantly higher on the JOBS and EXACT subscales as well. At the end of the course significantly higher scores for O/A level students are now found only in the COMMUNICATION and CONFIDENCE subscales. For the subscales showing statistically significant difference in their scores, both pre and post scenarios, the effect size has also been calculated and found to be between 0.20 to 0.60 suggesting a small to large effect size.

Results from the lagged regression models contained in Column (5) of Table 4 indicate that overall increases in the engineering attitude scale, COMBINED, as well as its subscales, from the beginning to the end of the EGR 100 course vary little with participants' secondary schooling. In this case the OLS lagged regression model may be represented as:

$$PFEAS_{Post} = a + b_1\ PFEAS_{Pre} + b_2\ SchoolType \quad \text{(where: O/A = 0, FSc = 1)} \qquad (9)$$

While Table 2 found no change in the EXACT subscale for EGR 100 participants as a whole, Column (3) of Table 4 shows that FSc level students did make significant gains in this subscale relative to participants from O/A level schools. Otherwise there were no significant differences in the subscales according to school type.

7. Interpretation of the findings

The significant and positive increases in the overwhelming majority of the subscales suggest that the course influences a wide range of student attitudes toward engineering. In particular, the results of Columns (4 and 5) of Table 2 demonstrate a significant increase, (both statistical significance (p-value) and practical/substantive significance (effect size), in the average performance of students in terms of their overall COMBINED attitude/behavior toward engineering between the beginning and the end of EGR 100. Moreover, ten subscales out of the fourteen subscales showed statistically as well as practically/substantively significant increases in the average attitude of the students suggesting that the change is not simply associated with one or two aspects of attitudes toward engineering. Between the beginning and the end of the course, participants developed more positive attitudes toward their future employment prospects, toward the contributions that engineers make to society, toward their enjoyment of courses of math and science, and the degree to which engineers are innovative and creative. At the end of the course they also held higher opinions of their ability in a wide range of skills, in their confidence in a variety of academic subjects, and in their ability to solve problems. They also held more positive views toward group work at the end of the course than at the beginning.

One subscale (Study) showed a statistically significant decrease in the average attitude of the students. The decline in this particular subscale between the beginning and the end of the EGR 100 course is also consistent with the conclusion that the course is having an impact on freshman engineering students. The items making up this scale query students regarding the adequacy of their study habits. An important element of the EGR 100 course content stresses that students reassess their previous study habits and reorient those habits in a manner consistent with the active learning model. Having received this message in the course one would expect that at the end of the course students would be less satisfied with their study habits.

Furthermore, for three subscales (Career, Exact and Family) the difference between the average behaviors of pre course performance as compared to post course performance is statistically insignificant. With the case of the Career and Exact subscales it may be the case that students already held strongly positive attitudes toward these aspects of engineering before beginning their studies. In the case of the Family subscale a possible explanation is that during the EGR 100 course the intrinsic worth of the engineering profession is stressed and little attention is paid toward the family's influence on the choice of engineering as a career.

With regard to gender differences in attitudes toward engineering we saw that females began their studies with significantly more positive attitudes than males toward engineering as a career and the benefits of engineering for society. However, in most aspects of attitudes toward engineering and in their overall attitudes there are no significant differences between males and females as they began their studies. At the end of the course, however, female students' overall attitudes toward engineering were significantly more positive than those of males, with particularly significant increases in the items valuing engineers as innovative and creative, and engineering as an interesting, respected and beneficial profession. Interestingly, at the end of the course there was no longer a significant difference in the subscale that measures parental influence on engineering as a career choice, with male students no more likely to agree that this is the case than female students. This was not the case at the start of the course, when males were significantly more likely to say that parents influenced their career choices. The significant regression coefficients reported in Column [3] of Table 3 indicate that overall, and particularly with regard to views toward engineering as a career and perceptions of the innovative, creative aspects of engineers and engineering as an interesting, respected and beneficial profession, greater gains were evidenced for females than for males.

The results of Table 4 show that the average scores in combined scale for students from FSc schools and O/A level schools were statistically indistinguishable in both pre-course and post-course measures. Thus, in terms of their overall attitudes toward engineering there appear to be no differences in students entering MEU from these two types of schools. However, the results do provide statistically and practically significant evidence that students from O/A level schools have higher average scores in the subscales —in the pre- and post-course measures—that capture their overall degree of confidence in their academic ability, and particularly in the subscale that taps into their confidence in their communication skills. A plausible explanation as to why students from O/A level schools enter the course with higher scores in communication and confidence than students from FSc schools is that the environment provided in the private schools that offer O/A level degree programs. Government/public sector schools, on the other hand, generally offer conventional FSc programs. A slight decrease is evident in the difference of the average performance of students in these measures at the end of the EGR 100 course suggesting that the course may be useful in enhancing the communication and confidence skills of students from FSc schools.

Meanwhile students coming from FSc schools in the pre and post course measures scored significantly higher on those items that capture positive attitudes toward the contributions that engineers make to society. In the post course measures students from FSc schools also scored significantly higher on items that represent positive views toward the job prospects of engineers and the extent to which engineering is an exact science that provides precise answers to problems. Though the regression analysis provided in Column [3] of Table 4 does not indicate a significant increase in these subscales for FSc students relative to O/A level students, the findings suggest that EGR 100 may have some impact on these dimensions for students entering MEU from an FSc school.

8. Discussion and future directions

Can teaching bring changes in the attitudes of freshmen opted for engineering career? This study makes several contributions to this issue based on the data of 718 students at a MEU in Pakistan. Attitudes toward engineering of a sample of students were assessed through a well-known instrument (PFEAS) with a variety of subscales measuring different dimensions of attitudes toward engineering. Data was collected both before and after a one credit course, EGR 100, designed specially to address misperceptions and misunderstandings of basic concepts of students pursuing engineering as a career. Various subscales articulated through PFEAS also showed statistically as well as practically/substantively significant increases in post course performance measures. Therefore, the study establishes a strong need for introducing and expanding cornerstone courses like EGR 100 for freshmen engineering students to improve their integration into engineering education, thus potentially enhancing their performance and adoption of the engineering profession in a rapidly changing global environment.

For the results related to gender, it was found that there is statistical evidence of an overall (Combined) positive difference in favor of females in the engineering attitude scale at the end of the course. Furthermore, the performance of females in the subscales Career, Society and Perception is better than males and improved further after taking the course EGR 100. This is an encouraging sign, especially for Pakistani society where females are grossly underrepresented in the engineering profession. Cornerstone courses like EGR 100 can play a significant role in reducing the wide gender imbalances in engineering in Pakistani society.

For the results related to the type of schooling, it was found that there is no statistical evidence of an overall (Combined) difference in the type of schooling on the engineering attitude scale. However, the attitude scores of students with an FSc school background is more positive than that of O/A level students on the subscales Jobs, Society and Exact while in subscales Communication and Confidence the performance of O/A level students is better than FSc, after the course EGR 100. In other words, the course decreases the differences between the communication skills and academic confidence of students from different educational backgrounds.

Another important aspect of the Pakistani basic education system is the lack of career counseling for students at the intermediate level (grades 9 through 12) to choose a relevant degree program before entering the university. Therefore, by providing an opportunity of learning through an extra credit cornerstone engineering foundation course like EGR 100, we can enhance (overall as well as in specific dimensions, as shown by the results of Table 2) students' attitudes toward engineering, and thereby reduce the incidence of dropout/career switching at early stages of their degree program.

There are, however, limitations to the study discussed in this paper. Addressing these limitations in subsequent studies may further improve EGR 100 in its scope and usefulness. First, there is a need to compare the changes in attitudes of EGR 100 students to a relevant control group, either through statistical comparison with other MEU students who were not enrolled in EGR 100 or ideally through random assignment of a group of MEU students to an EGR 100 study group and others to a control group not enrolled in EGR 100. As noted above, there was not a statistically significant difference in MEU entrance examinations between those who took the course and those who did not. Similarly, there was not a statistically significant difference in GPAs between the two groups after their first semester at MEU. In both instances the students who took EGR 100 outscored the other students. While a larger sample may establish a statistically significant difference in GPAs as an outcome measure, random assignment of students to EGR 100 would be necessary to determine whether or not this result is due to unmeasured differences (for example, other attitudes or motivations not captured by the PFEAS), among students self-selecting into EGR 100 or is an effect of EGR 100, confirming that changes in attitudes toward engineering also leads to better performance. Second, the PFEAS instrument should be studied in greater depth with regard to its weaknesses [4] and to determine if it requires further revision to match the Pakistani educational context, particularly with regard to engineering education. Third, additional research should pay greater attention to demographic and socio-economic characteristics of students that bear on how a course like EGR 100 influences students' attitudes toward engineering. Finally, while the PFEAS has been used to demonstrate the effectiveness of cornerstone courses in the U.S. and now also in Pakistan, there is a need for further work in other countries, particularly in the developing world. Apart from one small study in Malaysia, there is little research to support the wider applicability of the efficacy of such courses [35].

9. Conclusions

The results of this study provide statistical support encouraging the introduction of cornerstone courses for freshmen engineering students so that they may appreciate the importance of engineers and the engineering profession right at the onset of their degree program. The results showed that the course is useful in increasing positive attitudes of freshmen engineering students toward their profession and therefore it can be said that the course is successful in meeting its defined objectives. This enables them to undertake the program with a proper engineering mindset to develop into useful, innovative and productive engineers with the passion and skills to contribute toward the well-being of society. Moreover, the study shows that cornerstone courses may reduce gaps in attitudes toward engineering related to gender and type of secondary school preparation.

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Appendix A

EGR 100 at a glance

Design Aspects	Nature, Real Life, Tacit Knowledge, Basic Sciences, Scientific Approach, Engineering, Education, Educational Psychology, Linguistics, Human Psychology, Eastern Culture vis-à-vis Western Educational Systems.		
Course Objectives	• To boost passion for engineering. • To fuel subject specific curiosity. • To enhance self-confidence and self-esteem. • To link academics with real life. • To revisit the conceptual depth of foundational and basic science concepts. • To enable students to realize and connect with their own tacit knowledge (in everyday language). • To activate thinking processes. • To encourage them to develop a holistic approach to problem solving beyond text book solutions.		
Course Curriculum Outline	**Engineering Foundation** • Engineering Profession • Engineering Mindset • Engineering Approach • Engineering Tools • Engineering Ethics • Engineering Bodies • Engineering Prospects	**Knowledge Building** • Evolution of Knowledge • Knowledge Blocks • Prior Knowledge • Knowledge Connections • Knowledge Overhauling • Concept Building • Concept Inventories	**Skill Building** • Cognitive • Linguistics • Learning • Mind Mapping • Emotional Control • Realizing Dreams • Effective Communication
Delivery Methods/ Techniques	• ***Multiple Interactive Lectures*** delivered in seminar mode utilizing animations, engaging in colorful slides/ audio/video clips presented in a relaxed, informal, and friendly manner. • Andragogy techniques with real life examples. (http://www.peoi.org/courses/coursesen/adulted/resources/pedagogy%20or%20andragogy.pdf) • ***Story telling technique***. (http://www.storytellingandvideoconferencing.com/67.pdf) • ***Threshold concepts***. (https://www.sensepublishers.com/media/1179-threshold-concepts-within-the-disciplines.pdf) • ***Multi-disciplinary approach***. (http://www.connectedcalifornia.org/downloads/ll_what_is_multidisciplinary_integrated_curriculum_v2.pdf) • ***Concept Inventories (CI).*** http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_072625.pdf		
OMNI* **Techniques**	• Application of ***see through concept*** whereby complex concepts are disintegrated into constituent elements for easy understanding. • Reducing subjects in ***nouns-verbs-adjectives*** and using their generic templates for understanding the subjects in depth. • Scaffolding students' thinking with ***fifteen elementary knowledge constructs*** • Introducing ***knowledge grafting*** rather than seeding afresh (a variation of analogical techniques) • Providing a ***thematic hook*** implying reducing academic subjects into rather crude yet loveable and digestible ideas, e.g., management reduced to *more-with-less,* arithmetic reduced to *how many,* algebra to *how much,* aerodynamics to *harnessing storm,* etc. • Use of ***linguistic levers*** (extensions of componential analysis) for seamlessly interfacing academics with *personal neural network* • Conversion of socially acquired knowledge into scientific format thus activating ***tacit knowledge*** and making use of *experiential learning* thus transforming student into active learners • Introduction of **common sense** in *slow motion* • Understanding the ***understanding*** and differentiating it from *learning*		
Limitations Recognized	EGR 100 is in experimental stage and may be difficult to pin point which component(s) of this *multi-intervention approach* influenced the most.		

**OMNI: Open-ended Malik & Naveed Interventions. For details visit RCEE Conf Proc. 1 (2016), pp. 308–311, Universiti Teknologi Malaysia.*

Appendix B

Pittsburg Freshman Engineering Attitudes Survey (PFEAS)

This is a survey to elicit Freshman Engineers' opinions and feelings about engineering. Please do not spend more than 20 minutes to complete the questionnaire, so work as quickly as you can. Remember these are your own personal attitudes, not your friend's. For each question, circle the number that represents the way you feel today about the statement. Your first response is usually the most accurate for you. The scale is:

5 = Strongly Agree (SA); 4 = Agree (A); 3 = Neutral (N); 2 = Disagree (D); 1 = Strongly Disagree (SD)

Part 1: Demographics

Name (Optional):________________, Gender: M/F, Domicile: ____________________
Age Group: < 18 / 18 - 21 / 22 - 25 / > 25_, Basic Schooling District: ____________________________________
Medium of Instructions: Urdu/English/Mix, Languages Spoken: Unilingual/Bilingual/Multilingual
Stream of Edu: O-A /FSc/Other, Mother Tongue: Urdu/Punjabi/Pushto/Baluchi/English/Other
Number of Schools changed: 0 / 1 / 2 / 3 / >3, Number of Engineers in close family: ______________________
Father Occupation: Government Servant/ Businessman/ Agriculturist/ Doctor/ Engineer/ Scientist/ Teacher / Other
Mother Occupation: Housewife/Professional/Doctor/Engineer/Other, Program enrolled: __________________
Financial Status: Upper/Upper middle/Middle/Lower Middle/Lower, Registration No (Optional): ___________

Part-2: Survey

For each statement about engineering, please fill in the number that corresponds to how strongly you disagree or agree with the statement.

1. I expect that engineering will be a rewarding career.
2. I expect that studying engineering will be rewarding.
3. The advantages of studying engineering outweigh the disadvantages.
4. I don't care for this career.
5. The future benefits of studying engineering are worth the efforts.
6. I can think of several other majors that would be more rewarding than engineering.
7. I have no desire to change to another major (Management, Economics, Arts, Medicine, etc.)
8. The rewards of getting an engineering degree are not worth the effort.
9. From what I know, engineering is boring.
10. Engineers are well paid.
11. I will have no problem finding a job when I have obtained an engineering degree.
12. I am studying engineering because it will provide me with a lot of money; and I cannot do this in other professions.
13. An engineering degree will guarantee me a job when I graduate.
14. Engineers contribute more to making the world a better place than people in most other occupations.
15. Engineering is more concerned with improving the welfare of society than most other professions.
16. Engineers have contributed greatly to fixing problems in the world.
17. Technology plays an important role in solving society's problems.
18. Engineering is an occupation that is respected by other people.
19. I like the professionalism that goes with being an engineer.
20. I am studying engineering because I enjoy figuring out how things work.
21. I enjoy the subjects of science and mathematics the most.
22. I enjoy taking liberal art courses more than math and science courses.
23. Engineering is an exact science.
24. Engineering involves finding precise answers to problems.
25. My parents are making me study engineering.
26. My parents want me to be an engineer.

For the following subjects and skills, please circle the number corresponding to the response that describes how confident you are of your abilities in the subject or skill on a scale of 1 to 5 with 5 being strongest.

27. Chemistry
28. Physics
29. Calculus
30. Engineering
31. Creative thinking is one of my strengths.
32. I am good at designing things.
33. I consider myself mechanically inclined.
34. I consider myself technically inclined.
35. Writing.
36. Speaking.
37. Computer Skills.

For the following statements about studying, working in groups and personal abilities, please circle the number corresponding to the response that best describes how strongly you agree or disagree with the statement.

38. I need to spend more time studying than I currently do.
39. I am confident about my current study habits or routine.
40. Studying in group is better than studying by myself.
41. Most of my friends I "hang out" with are studying engineering.
42. I prefer studying/working alone.
43. In the past, I have not enjoyed working in assigned groups.
44. I feel I know what an engineer does.
45. I have strong problem solving skills.
46. I feel confident in my ability to succeed in engineering.
47. I enjoy solving open-ended problems.
48. I enjoy problems that can be solved in different ways.
49. Engineers are innovative.
50. Engineers are creative.

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