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Research Article

Establishing Research Instrument To Measure Inclusiveness Of Adaptive Methodologies In Engineering Education

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ABSTRACT

Engineering Education has been a key to socioeconomic growth of India (developing economy). However, during the last decade there has been less enrollment in engineering institutes especially across rural India which has even led to closure of some institutes. It is conjectured that this problem can be addressed by adaptive educational strategies. Hence it is necessary to understand the efforts taken by engineering institutes in practicing adaptive educational strategies. The objective of this study is to design and test a reliable survey instrument to understand the extent of existence of adaptive education in engineering educational institutes. For the same, a research survey instrument with 8 constructs involving 57 items related to adaptive educational techniques was developed.

A pilot survey comprising 61 students at various engineering institutes was carried out and its analysis was done using SPSS software.

The reliability test was carried out by checking Cronbach alpha. Research instrument so tested, found reliable since scale reliability for all constructs lies within permissible range.

Descriptive Statistics, demographics and related cross tabulation, and correlation between the constructs were established. Principal Component Analysis (PCA) was carried out.

It was found from the result that the constructs are independent of demographic variables. Out of 08 constructs, 04 are factorable based on BTS, KMO and PCA tests. The deviation of mean from the top ratings of likert scale indicates the need of adaptive system inclusiveness in almost all educational parameters. The Research instrument can be used for large sample surveys.

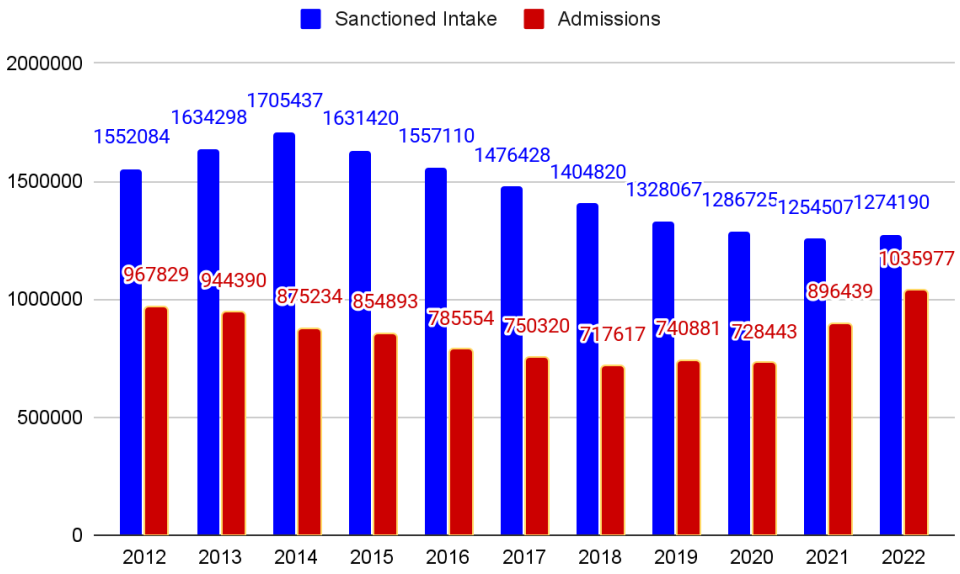
Keywords: research instrument, adaptive education, engineering, pedagogy.

Introduction

At the end of the 19th century (AICTE, 2003) there were only four engineering institutes in India. After 1950, India witnessed a rapid increase in the number of engineering institutes and overall intake strength. The number of engineering institutes increased from merely 50 institutes in 1950 to 3000+ institutes in the year 2022.

This rapid increase in overall sanctioned strength of engineering institutes provided an opportunity for large sections of society to receive engineering education which ultimately led to their economic upliftment. However, during the last decade enrollment in engineering institutes has reduced, which is summarized in Graph no. 1.

Graph1. Sanctioned Intake vs Actual admissions in Engineering (AICTE, 2022)



Due to less enrollment, institutes are experiencing financial difficulties. This has led to even the closure of some engineering institutes, specifically unaided private institutes. Unaided affiliated Institutes are those institutes which do not receive any government grant (Ministry of Education, AISHE, 2020). With the Intake capacity of nearly one million in 2022 (AICTE, 2022), unaided affiliated private institutes are the major engineering education providers in the country.

To address the problem of low enrollments, it is necessary to understand the efforts that the unaided affiliated institutes are taking for sustainable improvement in the areas of educational importance such as Curriculum, Teaching-Learning & faculty qualification, quality of students entering the institute, student diversity, student strength, graduation outcomes, student support, research & Innovation outcomes, Industry linkages, Infrastructure & Facilities, Governance and Stakeholder perception (National Board of Accreditation, n.d.; Assessment & Accreditation, n.d.; MoE, n.d.; CII, n.d.; MDRA, n.d.; times-engineering-survey, 2021)

Today's engineering education system should be able to prepare graduates that will make new discoveries, bring new products and services, design, and deliver to serve the communities and innovate continually to support the industries (Mohd-Yusof et.al. 2015). This is only possible by creating symbiosis between all educational actors: students, teachers, education managers and administrators in a common endeavor for improving the education practices (Mogos et.al. 2018). Improving learning experience, focusing on the learning and not teaching, fostering creativity and innovation in education is the need of today's engineering education (Morell 2010). The "One size fits all "type of traditional education system can satisfy these needs only if they are supported by adaptive educational strategies. However, these techniques are accessible to all; whether really implemented by the unaided- University affiliated institutions is the question whose answer needs to be found.

Literature review section provides the review of adaptive educational strategies already being suggested by various academicians and researchers.

Literature Review

Adaptive education, also known as personalized learning, is an approach to education that leverages technology and data to customize the learning experience for individual students. The goal of adaptive education is to tailor instruction, content, and pacing to meet each student's unique needs, abilities, and learning preferences.

Adaptive systems use information about a particular user, reflected through the user record, to adjust the information presented to that user (Srisethanil & Baker 1995). These systems build a model of the goals, preferences and level of knowledge of each individual student in order to adapt his/her needs of special and general education in a regular classroom setting (Verdu et.al. 2008, Wang et. al. 2010). Adaptive education tunes learning material and teaching methods (Nguyen 2008). Adaptive education not only improves the cognition ability of the students but also has substantial effect on behavioral and affective domains of student learning (Waxman et.al., 1985). Adaptive education also helps students to feel they belong in an institutional culture, where they experience good quality teaching and support for their learning (Zepke, Leach & Prebble, 2006). Adaptive education helps students not only in knowledge gathering but also it helps in prioritizing, time management, help-seeking behavior, knowing professors' expectations and critical self-evaluation (Concannon et. al., 2019).

In the adaptive system of education, the tutor continuously monitors and diagnoses the student's learning process and determines the next instructional actions (Lee & Park, 2004; Allen, Webb & Matthews, 2016). Hence the willingness of students as well as teachers is of paramount importance in the success of adaptive education (Al-Othman et. al., 2017; Tudor, 1993). In adaptive education, teachers are expected to improve: the knowledge and skills, to include higher-order cognitive, psychomotor, affective and social skills (Johnston et. al. 2015). Teachers must have knowledge about what students know and what students need to know. Teachers should be able to create a link that connects the real-world connections and alter their instructions in a productive way (Allen, Webb & Matthews, 2016). Teachers must be confident enough to implement adaptive strategies in the classroom (Chen, 2007). Teachers' professional knowledge in information technology, and the teacher's creative solutions to problems arising in the teaching process etc. affect the success of the adaptive system (Pundak & Rozner, 2008).

Adaptive education makes use of a variety of curricula and techniques that have proven effective in many types of classroom settings and with a diversity of students. These include mastery learning, cooperative teams, and individual tutorials, as well as large and small group instructional approaches (Wittrock, 1986). Instructional techniques used in adaptive systems which had shown distinct results includes project based learning (Uziak, 2016; Mills & Treagust, 2003), Challenge Based Learning (Jou, Hung, & Lai, 2010), Decision Making Games (Durlach & Lesgold, 2012), Simulation Games (Deshpande & Huang, 2011; Prauzner, 2016) Inverted Classroom (Ahmed, 2013; Mason, Shuman, & Cook, 2013), Virtual reality (Abulrub, Attridge & Williams, 2011), Industrial visits and Guest Lectures (Madheswari & Mageswari, 2020; Piper & Krehbiel, 2015). The success of these techniques depends upon the feedback loop between learners and educators and how quickly educators adjust the instructional deliveries based on the feedback (Lian, 2003). Formative assessment provides agility to the feedback loop and hence it has to be used frequently and in a manner such that the outcomes of the curriculum can be measured effectively (Rust, 2002; Jadhav et. al., 2020). Apart from the summative and Formative assessment; course completion rate, guided projects, learner feedback (Hallifax et.al., 2019) can effectively be used in learner's assessment. The assessments shall involve active engagement by students. Self as well peer assessment to be encouraged (Rust, 2002). However the only pedagogical advancements will not intensify the adaptive educational approach because adaptive education is not just an adaptation of pedagogy, instead it is a positioning process (Barakhsanova et.al., 2016; Tyre & Hippel, 1997). The entire student learning experience needs to be optimized by using the Learning Management System, open educational resources and technology led instructions and assessments (Ahmed, 2013; Andersen et. al., 2020).

The impact of technology on adaptive systems is governed by how fast teachers and employees better understand the technology and what it can do for education (Klaassen, De Vries, & Kamp, 2017). Often this process is very slow and resisted by the academicians (Pundak & Rozner, 2008). Thus, despite great potential, adaptive education is practically difficult to implement. Hence efforts should be made to build an adaptive education system on existing educational practices (Schweisfurth, 2013; Al-Zu'be, 2013; Subramanian & Kelly, 2019).

The extent of overlapping of conventional and adaptive educational systems will determine the learning experience of the students. The higher the overlap, the better will be the learning experience.

The position of the adaptive educational system in engineering education needs to be identified. The effective way of doing this is to take a survey on the presence of adaptive educational systems in engineering institutes from the most important stakeholders i.e. students.

Objective of the study

Thus, from literature review, it is noted that adaptive education can play a significant role in improving the learning experience of students in engineering institutes. However, its practical implementation is challenging. To understand the state of adaptive education, a research survey instrument needs to be designed and developed scientifically. Thus, the aim of the study is designing and testing a reliable survey instrument to understand the extent of existence of adaptive education in engineering educational institutes.

Development of Framework for Survey Instrument

While designing a survey instrument the following aspects of adaptive education were considered.

Curriculum Flexibility: University-prescribed curricula may not always cater to the diverse requirements and interests of students and accordingly curriculum needs to be flexible.

Innovative Pedagogy: Innovative teaching and learning methods such as project-based learning, problem-solving exercises, simulations, and other active learning strategies that engage students and address their specific learning needs are essential for an adaptive education system.

Effective Use of ICT: Effective use of ICT facilitates personalized learning experiences, provides access to a wealth of educational resources, and promotes interactive and collaborative learning.

Assessment, Evaluation, and Feedback: Adaptive education should include a robust system for assessing student progress, evaluating their understanding of the material, and providing timely feedback. This allows students to adapt and improve their performance based on their individual needs.

Individualized & Self-Paced Learning: Recognizing the uniqueness of each student and adapting the pace and content delivery to their individual needs is a cornerstone of adaptive education. This approach acknowledges that students have different learning styles, paces, and goals.
Alignment with Aspirations: Adaptive education should support students in achieving their career and academic aspirations. By tailoring the curriculum and learning experiences to align with students' goals, it can motivate them to stay focused and work toward measurable outcomes.
Overall; adaptive education in engineering institutes seeks to create a student-centered learning environment where the educational system adapts to the needs of individual learners, fostering their personal and professional development. It promotes flexibility, innovation, and the use of technology to enhance the quality and effectiveness of education in an ever-evolving field like engineering.
Table No. 1 provides the definition of constructs identified and formulated based on the literature review.

Table No. 1. Conceptualization of potential areas of adaptive education as a survey construct

Construct	**Brief Definition**	**Reference number of inspiring prior literature.**
Curriculum	Students' experience about incorporation of flexibility in the university prescribed curriculum at the institute	(4-9), (27), (34)
Teaching-Learning	Students' experience about consideration of individual learning needs by the instructors	(40-42)
Exposure	Sensitizing students towards ethical, social, career and professional requirements	(10)
Research & Innovation	Students' experience about research culture in the institute	(4-9)
Use of ICT	Students' experience about the digitization of allied educational activities the institute	(15), (34), (45)
Progression	Students' experience about the efforts taken by the institute to make students industry ready	(12-14)
Programme Outcomes	Students' level of confidence on inculcation of engineering attributes in them during their academic tenure	(12), (40-41)
Pedagogy	Students' experience about pedagogy methods used in classrooms	(27-38)

A survey instrument with 60 items was framed based on the constructs developed. The survey instrument was validated using face validity. Applicability or redundancy of items were examined. Ten participants were asked to provide comments & suggestions in this regard. After reviewing the comments, the possible changes and consequences were discussed and the decision of removing three items was taken. As a result, 57 items were available for pilot study.
Nine items on width and breadth of curriculum offered by the institute were grouped with seven-point likert scale under construct "Curriculum". Five items on incorporation of individuality in teaching-learning were grouped with seven-point likert scale under construct "Teaching-Learning". The questionnaire also contained the items on exposure to fourteen different pedagogy techniques with a five-point likert scale. These questions were grouped under the construct "Pedagogy". The questionnaire also contained a group of eight items with a seven-point likert scale on the opportunities and exposure provided to the learners. These items were grouped under the construct "Exposure". Two items on research and innovation with a six-point likert scale were grouped together. Five items related to the extent of use of ICT in various educational functionalities were grouped with a six-point likert scale under construct "ICT". To understand the institute's efforts in helping students in their career/academic progression; seven items with seven-point likert scale were grouped under construct "Progression". To understand the students' confidence in achieving the generalized educational outcomes, seven items with seven-point likert scale were grouped under "Programme Outcomes".

Methodology

Data Collection

A random group of 62 students at Unaided affiliated institute was given a self-descriptive questionnaire out of which 60 students anonymously completed it. Students from second year onwards were selected for the survey.

Data Analysis

The feedback from students was taken on the clarity of questions in the questionnaire. Descriptive Statistics, demographics and related cross tabulation, Tests of scale reliability, and correlation between the constructs were established with the help of SPSS software. Correlation between two constructs, correlation between constructs and age group & between constructs and family income were calculated using Spearman's Correlation coefficients. Correlations between constructs and other demographic variables were calculated using Biserial Coefficient.

Based on the test of scale reliability, Principal Component Analysis (PCA) with Oblimin rotation was carried out because it was assumed that the factors would be correlated.

Visual scree test and the traditional method of producing eigenvalues by PCA were used to determine the appropriate number of factors to retain. Theoretical convergence was also considered. Further for statistical identification, a factor comprising at least three measured items were considered (Watkins, 2018). Given the number of respondents to the questionnaire, pattern coefficients ≥.51 were considered salient (Watkins, 2018). Complex loading of salient pattern coefficient was rejected to obtain a simple structure. Factors with minimum three salient pattern coefficient, internal consistency reliability ≥ .70 and that were theoretically meaningful were considered adequate.

Results

The group comprised 31 (50%) male and 31 (50%) female students. Out of 31 Male students, 25 (81%) were belonging to 18-21 age groups and others from 22-25 age groups. In case of girls, 18 (58%) were between 18-21 age group and remaining between 22-25 age group. 27 (87%) Male and 27 (87%) female represented the Circuit branches and the remaining were from Non-Circuit branches. Total 60 students provided responses related to the student category. Out of 60 students 32 (52%) were from the Open category and 28 (48%) were from the Reserved category. 15 (48%) male students and 19 (61%) female students were belonging to the income bracket of Nil to 1 Lac.

Based on the survey results of individual items, mean of means for every construct was calculated. All the constructs except Pedagogy (M= 3.60, SD= 0.60) showed slight (-)ve skewness. Scale item reliability estimates (Cronbach's Alpha) were found in the .71 to .86 range. Table No. 2 depicts means, standard deviations and Cronbach's Alpha for all constructs.

Table No. 2. Descriptive Statistics and Scale Reliability Test results

Sr. No.	Code	Construct	Mean	Standard Deviation	Cronbach's Alpha
01	CR	Curriculum	5.88	0.69	0.82
02	TL	Teaching-Learning	5.89	0.71	0.71
03	EX	Exposure	5.27	0.92	0.82
04	RI	Research & Innovation	4.47	1.01	0.72
05	ICT	Use of ICT	4.87	0.84	0.80
06	PR	Progression	5.7	0.95	0.86
07	PO	Programme Outcomes	5.5	0.92	0.85
08	PG	Pedagogy	3.6	0.6	0.78

Constructs and all demographic variables showed low correlation with a maximum Biserial correlation of $r(57) = .22$, $p = 0.09$ between nominal variable student category and construct Teaching- Learning in positive direction. Maximum Spearman's Correlation coefficient was $rs(59) = -.39$, $p = 0.002$ with negative correlation between demographic variable age group and construct exposure.

Between Constructs; Exposure is strongly correlated to Progression $rs(59) = .62$, $p < 0.01$ and Pedagogy $rs(59) = .60$, $p < 0.01$. Curriculum shared a strong positive correlation with Teaching-Learning $rs(59) = .67$ $p < 0.01$. All other moderate and weak correlations are tabulated in Table No. 3.

Table No. 3. Correlations between Constructs

		CR	TL	PG	EX	RI	ICT	PR	PO
CR	r_s	1.000	.669	.381	.523	0.244	.529	.370	.473
	p		0.000	0.002	0.000	0.059	0.000	0.003	0.000
TL	r_s	.669	1.000	.351	.436	.406	.395	.578	.532
	p	0.000		0.005	0.000	0.001	0.002	0.000	0.000
PG	r_s	.381	.351	1.000	.602	.394	0.195	.508	.380
	p	0.002	0.005		0.000	0.002	0.132	0.000	0.003
EX	r_s	.523	.436	.602	1.000	.467	.419	.620	.555
	p	0.000	0.000	0.000		0.000	0.001	0.000	0.000
RI	r_s	0.244	.406	.394	.467	1.000	0.200	.488	.460
	p	0.059	0.001	0.002	0.000		0.122	0.000	0.000
ICT	r_s	.529	.395	0.195	.419	0.200	1.000	.350	.324
	p	0.000	0.002	0.132	0.001	0.122		0.006	0.011
PR	r_s	.370	.578	.508	.620	.488	.350	1.000	.574
	p	0.003	0.000	0.000	0.000	0.000	0.006		0.000
PO	r_s	.473	.532	.380	.555	.460	.324	.574	1.000
	p	0.000	0.000	0.003	0.000	0.000	0.011	0.000	

r_s: Spearman Correlation Coefficient, p: Statistical Significance of null hypothesis
Correlation range: 0 to 0.4: Weak, 0.4 to 0.6: Moderate, 0.6 & above: High (Prion & Haerling, 2014)
For all correlations, Degree of freedom: 59

As the scale reliability for all constructs lies in between .71 to .86 range, Bartlett's test of sphericity (BTS) was used to ensure that the correlation matrix was not random and the KMO statistic was required to be above a minimum of .6. Determinant values above 0.0001 are required to obtain a factor analytic solution. After confirming that the correlation matrix for respective constructs were factorable except constructs Teaching-Learning (KMO= .58, BTS= <0.01), and Research & Innovation (KMO= .5, BTS= <0.01); they were submitted to Factor Analysis.

For construct "Curriculum", scree plot and eigenvalues suggested that the three factors should be retained but only one item (CR3) was saliently loaded on the third component hence it was rejected. Factor one with loading of five items (CR2, CR4, CR5, CR8, CR9) had internal consistency (alpha) reliability .81 and second factor with salient loading of three items (CR1, CR6, CR7) had internal consistency (alpha) reliability .73. 43% of the total variance was explained by factor one and 14% of the total variance was explained by the second factor. Two factors were accepted and the third factor was rejected in a three factor solution.

For construct "Pedagogy", scree plot and eigenvalues suggested that the four factors should be retained, however a three factor solution found to be more comprehensive with salient loading of four items (PG2, PG9, PG10, PG11) on factor one, three items (PG3, PG4, PG8) on Factor two and four items (PG6, PG7, PG12, PG13) on factor three with internal consistency (alpha) reliability for all three factors ranging between .61 to .79. Three items (PG1, PG5, PG14) were rejected because of low pattern coefficient values. Factor one, two and three accounted for 27%, 15% and 13% of total variance respectively.

For construct "Exposure", scree plot and eigenvalues suggested three factor design. One item (EX 1) was complexly loaded on two factors hence rejected. Three items (EX2, EX3, EX4) were saliently loaded on one factor with internal consistency (alpha) reliability .76. Each of the other two factors were explicitly loaded with only two items and hence rejected. The variable was also examined for two factor design. Five items (EX1, EX2, EX3, EX4, EX7) were saliently loaded on one factor and two items (EX5, EX6) saliently loaded on other factor and hence rejected. EX8 rejected because of the low coefficient value. Factor one accounted for 46% of total variance with internal consistency (alpha) reliability .81. Given the results, factor one of two factor results was accepted.

For construct "Use of ICT" scree plot and eigenvalues suggested single factor design hence all items (ICT 1 to ICT 5) were grouped together under single factor. 56% of the total variance was reported by the factor.
For construct "Progression", scree plot and eigenvalues suggested that the two factors should be retained with salient loading of four items (PR2, PR3, PR6, PR7) on factor one and two items (PR1, PR4) on factor two. Factor two is rejected because of two item loading. Factor one accounted for 56% of total variance with internal consistency (alpha) reliability .84.
For construct "Programme Outcome", scree plot and eigenvalues suggested that the two factors should be retained with salient loading of four items (PO1, PO2, PO3, PO5) on factor one and three items (PO4, PO6, PO7) on factor two. Factor one accounted for 54% of total variance with internal consistency (alpha) reliability .91. Factor two accounted for 28% total variance with internal consistency (alpha) reliability .88.

Discussion & Conclusion

Research instruments designed to understand the adaptive educational system acceptance by unaided engineering institutes were tasted and found reliable. Suggested constructs are independent of demographic variables. Among 08 constructs; 04 variables viz. Curriculum, Pedagogy, Exposure & progression and Programme Outcome are factorable based on BTS, KMO and PCA tests.
The deviation of mean from the top ratings of likert scale indicated the need of adaptive system inclusiveness in almost all educational parameters. The Research instrument can be used for large sample surveys.

Limitations

The study was carried out by conducting a survey among a focused group of 62 students. Hence full scale study with large sample size is required to address the population.
The Research instrument was designed and tested only for one stakeholder i.e. students. Research instruments to survey other stakeholders such as teachers need to be designed.

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