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Developing an Instrument to Measure the International Engineering Educator Certification Program Participants' Learning Experiences

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ABSTRACT

This paper focuses on the design and development of an educational survey instrument that will effectively measure the participants' self-rating of competence and professional confidence acquired through a given faculty development program. To develop the instrument, a nine-months long engineering faculty development program - IUCEE International Engineering Educator Certification Program (IIEECP) was chosen, and the developed instrument was implemented on Indian IIEECP certified faculty. The IIEECP program is a specially designed certification program designed to improve the pedagogical acumen and professional confidence of Indian engineering educators. For this study a total of 193 participants were recruited and effort was made to capture as diverse a population as possible. The sample included 59 percent women and 41 percent men teaching different engineering disciplines in different types of engineering institutions in India. The survey instrument is designed in three part that include i) demographic analysis, ii) a 39-item questionnaire related to the achievement of specified learning outcomes of the IIEECP program, and iii) a set of six qualitative questions designed to help participants rate their enhanced competencies and professional confidence. An exploratory factor analysis (EFA) was conducted to examine the factor structure of the survey instrument under consideration. The EFA revealed six distinct factors each corresponding the six different modules. The Cronbach's alpha for the six factors ranged between 0.82 and 0.87, indicating high internal consistency between the items. The study serves as an effective measurement tool for faculty, engineering institutions as well as the IIEECP expert team. For the faculty, it provides a practical tool for self-reflection; for the institutions it allows to develop criteria for faculty readiness and identify their training needs. For the IIEECP team it provides invaluable feedback to further refine and reinforce the program. The designed instrument demonstrates how the efficacy of faculty development programs can be measured through participants rating of acquired competencies and confidence. One of the limitations of this work is that the evidence for content validity was not collected. The instrument will benefit from evidence collected from the expert team teaching and evaluating each module of IIEECP*.* Investigating the influence of participants' demographic variables on participants' performance and professional confidence is another direction for future work.

Keywords: effective teaching, exploratory factor analysis, faculty development, international certification program, survey instrument

Introduction

India is known to be the global hub of engineering education with over 1.5 million engineers graduating every year. Today, India has over 3,500 engineering institutions that can be classified in different tiers. Except for the graduates coming from elite, top ranking engineering institutions like the Indian Institutes of Technology (IITs) or the National Institutes of Technology (NITs), the un-employability rate amongst Indian engineering graduates is alarming. Citing the latest report by All India Survey on Higher Education (AISHE, 2019-2020) issued by the Ministry of Education, India, one commercial magazine claims that nearly 80% of engineering graduates are unemployable [1]. The information is confirmed in another article

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"80% of Indian engineers not fit for jobs - says survey" by a reputed business magazine (Business Today, March 25, 2019).

A well-recognized reason for this unhappy situation is the lack of pedagogy-savvy faculty and the use of outdated teaching practices leading to poor preparation of students for a demanding workplace. Over time a lot of national and international resources have been spent in faculty development mainly in the form of short 5-10 days workshops. In 2007, a group of American engineering educators of Indian origin came together to form a volunteer organization for improving engineering education in India. The organization initially named as Indo-*US* Collaboration for Engineering Education (IUCEE) was soon renamed as the Indo-*Universal* Collaboration for Engineering Education when other educators from Singapore and Australia joined the organization. The IUCEE also started its activities with a series of conventional one-week long faculty training programs. Over 2008 -2010, more than 2500 faculty from all over the country were trained. However, it became clear that in order to bring in sustainable change in the competency and confidence levels of the faculty, a more formally structured training program needs to be designed which would include theory and a substantial practicum component.

Faculty development programs (FDPs) for university faculty focused on improving teaching skills began in the early 1970s internationally and since then there have been numerous FDPs conducted nationally and internationally [2]. The duration of the faculty development programs is usually in the form of a day, three-days, five-days, two-weeks, etc. Different research studies on the effectiveness of FDPs present minimal assessment of the activities of simplistic measures mostly relying on participant feedback or satisfaction surveys [3]. A few exceptions exist, for example, researchers assessed the outcomes of the FDP after the completion of the program by collecting data from observing faculty members teaching and analyzing them [4]. Six faculty members teaching in the clinic and/or in the classroom were observed and interviews were conducted to collect data. In a study, by Hoffmann-Longtin et al., [5], focused on understanding the trends on assessment on FDPs, summarized that there is need to shift the focus on assessing the impact and outcomes of FDPs and the data collection methods for evaluating the effectiveness of the FDPs must be critically designed. With this as a brief background and motivation, in this study the authors present a survey instrument designed following the outcomes of a nine-month long certification program which aimed at assessing the participants self-assessment of their competency in their confidence on performing different tasks learned in the certification program.

Per se, a single assessment tool cannot be used to assess different programs as the needs and defined goals/outcomes of different programs vary. However, the approach presented in the paper can be used to design survey instruments to measure participants personal perceptions related to the different outcomes of the faculty development program.

Design Framework for IIEECP

In 2014, the IUCEE invited a reputed education technologist (Dr. Veena Kumar, retired Professor and Head, education Technology, Indian Institute of Technology, Delhi, India) to design a comprehensive certification program - the IUCEE International Engineering Educator Certification Program (IIEECP), inspired by a similar certification program offered by IGIP (translates in English as the *International Society for Engineering Pedagogy*), Austria. IGIP is a renowned European engineering society with over 40-year tradition of making valuable contribution to engineering pedagogy and faculty development. IGIP has certified over 1500 faculty in 52 countries (Wikipedia).

As the IIEECP program was fully customized to meet Indian education, socio-economic, cultural ground realities, it was quite different from the certification program offered by IGIP. However, both programs covered similar theoretical, ethical, and practical issues, and both led to a valuable certification in engineering pedagogy. The IIEECP was formally launched in January 2015 with the financial support of Microsoft India. In 2016, IGIP recognized the IIEECP for joint certification. The underlying philosophy of IIEECP is to focus on developing both

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professional skills and personal growth (Figure 1). The most challenging of all was to bring in a new mindset that distinguished a good academician from a good teacher, and conceptually recognizing that teaching was a skill that needed to be learnt with time and effort.

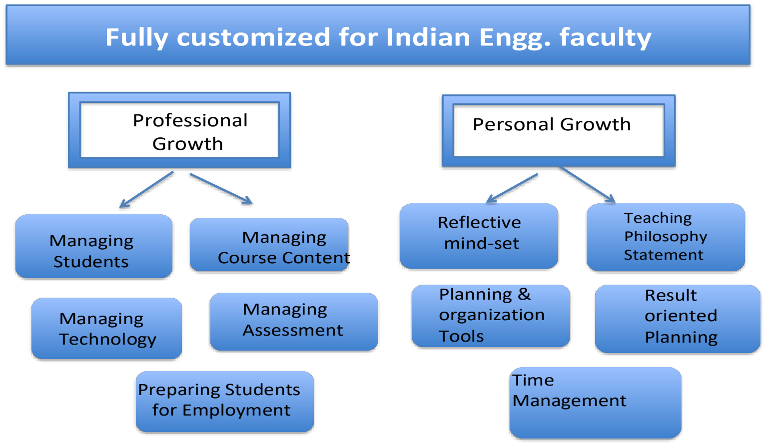

Figure 1: Underlying philosophy of IIEECP

IIEECP Program Format

The program was designed to be delivered in three phases:

1. Phase I, three days face–to-face workshop to discuss key theoretical concepts.
2. Phase II one semester long practicum program, delivered in blended mode. The participants are expected to be teaching a regular course during this phase where all strategies learned will be implemented and evaluated through student feedback. Weekly assignments and thought-provoking discussions form an integral part of this phase. Each assignment includes a brief reflective report on the strategy practiced.
3. Phase III involves submission of a teaching portfolio and a capstone presentation to reflect upon and assess ones' own learning and developing a personal plan for teaching.

Program Content

The program input is packaged in six modules, each module addressing an important component of the higher-education pedagogy. The specific learning outcomes of each module that form the bases of the instrument are listed below.

Module 1 - The Teaching- Learning Process

At the completion of this module, the participants will be able to:

- Summarize major theories of learning propagated by educationists such as Skinner, Piaget, Vygotsky, Maslow, and Gardner.
- Identify academic & employment needs of Millennial and generation Z learners
- List the three domains and levels of Bloom's Cognitive Taxonomy
- Summarize Theories of Motivation.
- Design lectures using the Keller's ARCS Theory of Motivation
- Incorporate Joseph Lowman's 2-D Model of Effective Teaching in course delivery Compose a personal teaching philosophy statement including short and long-term goals for personal and professional development

Module 2 - Course Design & Delivery

At the completion of this module, the participants will be able to:

- Compose course learning outcomes using Bloom's taxonomy & aligning them to institution's program objectives.
- Sift and sequence content to plan independent study projects.
- Incorporating MOOCs and other open sources in your course.

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- Design an effective lecture incorporating active learning
- Design and implement a Flipped class.
- Planning an effective first day of a new course.

Module 3 - Creating a Dynamic Classroom
At the completion of this module, the participants will be able to:

- Identify and manage student differences in terms of background, preparation, learning styles, demographic differences, and linguistic competencies.
- Design and implement the 12 commonly used active-learning activities (summarizing, think pair & share, minute papers, verbal quizzes, TAPPS, etc.) within lecture time.
- Implement active learning activities in a large class.
- Manage disruptive student behaviour in class.

Module 4 - Collaborative Learning
At the completion of this module, the participants will be able to:

- List importance of collaborative learning in attaining graduate attributes.
- Design and implement project-based learning pedagogy.
- Plan different steps for preparing and implementing Collaborative activities.
  - selection of topic, creating teams, designing problems, creating assessment and rubrics for evaluating individual and group performance and collecting student feedback.

Module 5 - Harnessing the Power of Technology
At the completion of this module, the participants will be able to:

- Create a dedicated course website using free resources.
- Use simple freely available technology options like ‘polls everywhere’ and ‘mentimeters’ to enhance classroom instruction.
- Record video/audio materials to support classroom/online teaching.
- Use animations and simulations.
- Identify and use Virtual Labs effectively.

Module 6 – Effective Assessment
At the completion of this module, the participants will be able to:

- Distinguish the role of assessment ‘for learning’ and ‘of learning’.
- Write good questions and mapping them to Bloom’s taxonomy.
- Manage in-class questioning and verbal quizzes.
- Create assessment for group work.
- Create Holistic and analytical rubrics.
- Use the sandwich model for providing constructive feedback (written and verbal).

The following sections provides details of the methodology used: development of survey instrument, the number and profile of the sample, process of data collection, and exploratory factor analysis, results and conclusions arrived at.

Methods

Development of the Survey Instrument

The survey instrument for this study was developed in Spring 2021 by the authors. The instrument includes six scales each corresponding to each of the six modules. Survey items were framed based on specific learning outcomes of each module. The instrument is intended to capture the IIEECP certified faculty members personal assessment of enhancement in their competencies and confidence level as a result of attending the certification program. The survey instrument is designed in three part that include i) demographic analysis, ii) a 39-item questionnaire related to the achievement of specified learning outcomes of the IIEECP program, and iii) a set of six qualitative questions designed to help participants rate their enhanced competencies and professional confidence.

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The survey items were initially written by the first author and were reviewed by the second author. The survey items were revised based on the feedback from the second author. Table 1 provides the overview of the survey instrument which includes the six scales, description of each scale, number of items in each scale and sample items for each scale. The faculty respondents were asked to rate their confidence in accomplishing participants' tasks related to skills learned in each of the six modules on a five-point Likert scale with response options (1) strongly disagree (2) disagree (3) neither agree nor disagree (4) agree (5) strongly agree.

Table 1: Overview of Scales of the IIEECP Survey Instrument

Scale (# of Items)	Sample Items
The teaching-learning process (7)	• I can define major theories of learning required in teaching my courses. • I can design my lectures using the ARCS model of motivation.
Course design and delivery (7)	• I can design my course using backward design. • I can implement an independent study program which helps me to complete my course in time.
Creating a dynamic classroom (7)	• I can design activities for generating intellectual excitement. • I can manage students with disruptive behavior.
Harnessing the power of technology (6)	• I can deliver online classes effectively. • I can effectively use virtual labs in laboratory courses.
Collaborative learning (5)	• I can effectively implement collaborative activities. • I can create instruments for evaluating group performance in a collaborative activity.
Effective assessment (7)	• I can create effective rubrics for class assignments. • I can effectively deal with unethical practices during assessments

The evidence for content validity was gathered from the second author, as the second author is closely associated with the design and development of the certification program. In this study, no external experts were recruited to provide feedback on the clarity, relevance, and appropriateness of the survey items. The evidence for the face validity of the survey instrument was collected by asking two potential participants to provide feedback on the complete survey addressing issues related to wording, clarity, and phrasing of the survey items.

The Sample – Numbers & Profile

The target population for this study were Indian faculty members who had completed the IIEECP certification. The survey was distributed to around 900 certified faculty members across India. A total of 280 faculty members responded to the survey which resulted in a response rate of approximately 31%. Most of the respondents were from the 2019 & 2020 batches. First the certified faculty members email addresses were collected, and the potential participants were invited to complete the survey through email during Spring 2021.

As mentioned, a total of 280 responses were received. The participants responses included six blank responses, three participants responded to less than 50% of the questions, and 78 participants responses were same on all the questions (they strongly agreed or agreed or disagreed on all the questions in the survey). The final sample after cleaning the data included 193 responses.

Table 2 shows the respondents' profile and demographic information. The sample included 59 percent women and 41 percent men, 54 percent faculty from the autonomous institution, and 31 percent faculty from affiliated universities. Most faculty completed IIEECP in 2020 (36%) and in 2019 (29%). About a third of the faculty held assistant professor positions (68%). The final sample after cleaning the data included 193 responses from ten different states, a pictorial representation of the participants respondents from different parts of India. Figure 2 shows the respondents' representation from different parts of India.

Table 2: Faculty Respondents Demographic Information

Category	Description	
	n	%
Gender		
Male	113	59
Female	80	41
University Setting		
Autonomous institution	104	54
Affiliated to university	59	31
Private university	30	16
Current Position		
Assistant professor	131	68
Associate professor	36	19
Professor	17	8
Others	9	5
Academic Department		
Electrical & electronics engineering	23	12
Computer science engineering	41	21
Mechanical engineering	23	12
Civil engineering	08	4
Electronics and communications engineering	45	23
Humanities	19	10
Others	34	18

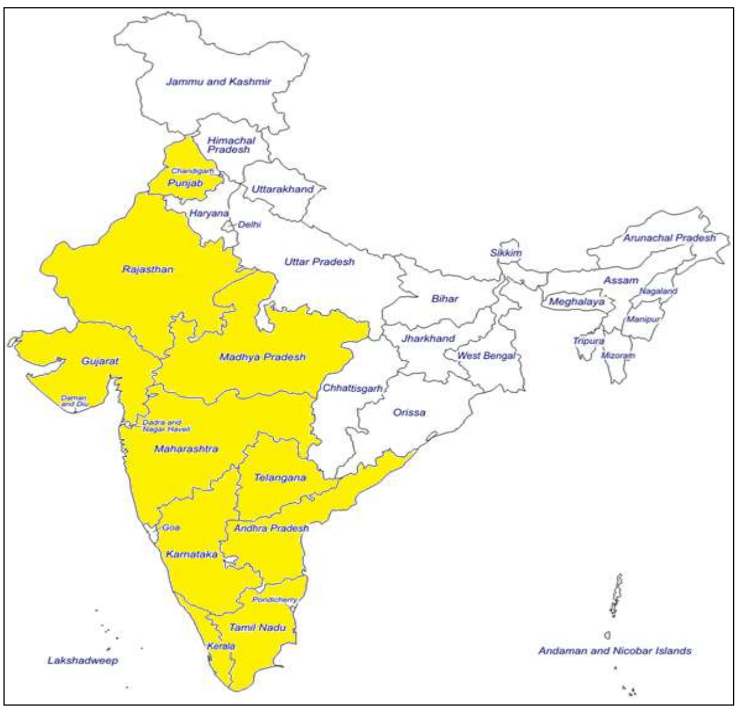

Figure 2: Faculty respondents' representation from different parts of India

Data Collection Procedure

The invitation to complete the survey was also sent through WhatsApp and Telegram networking apps. Two follow-up reminders were sent to the potential participants to complete the survey. The participants who completed the survey did not receive any remuneration. All responses were critically scanned for errors and completeness. Responses with missing information were removed to avoid the biases that it would bring in the analyses. Participants who did not respond to more than 50% of the questions on the survey were deleted, participants with same responses for all the questions were also removed from the data. The missing data on the survey items was handled using the group mean substitution method. To ensure significant correlation among the items with one another in each scale, inter-item correlations were examined. The suitability of the survey items for factor analysis was determined using the Bartlett's test for sphericity (*p<0.05*). To check the meaningful variance among the extracted factors from the survey items, Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was used.

Exploratory Factor Analysis

To investigate the fundamental factor structure of the IIEECP survey instrument and the items that belong to each scale, exploratory factor analysis (EFA) was conducted. Principal axis factoring was used to extract the factors and Promax with Kaiser normalization method (kappa=4) was used as the rotation method. To determine the number of factors to be extracted from the data, Kaiser's criterion, parallel analysis, and scree plots were used [6]. Items that had low loadings on all factors (<0.4) or cross loadings on at least two factors (>0.3) were removed from the factor structure [6]. This process was repeated until there were no low- or cross-loading items remaining. With the finalized factor structure for the scales of the survey instrument, Cronbach's alpha (α>0.8 preferred) was used to calculate the internal consistency reliability for each scale of the instrument [7]. The final scores for each scale were calculated by averaging the scores of all items associated with that scale.

Results

The suitability of the IIEECP survey instrument was confirmed by the Bartlett's test of sphericity (*p<0.001*) and the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) indicated that if factor analysis was conducted then the extracted factors would account for meaningful variance (KMO=0.946) [6]. Scree plots, parallel analysis, and Kaiser's criterion methods suggested extracting three, five, and six factors respectively from the data. The authors decided to develop the instrument with six factors as this matched the number of hypothesized factors. The inter-item correlations for each of the hypothesized scales were significantly correlated (*p<0.01*), thereby supporting a six-factor structure of the instrument.

Two items – "I can design my lectures using the ARCS model of motivation" (The teaching-learning process) and "I can map advantages of including collaborative activities with promoting graduate attributes" (Collaborative learning) – had factor loadings less than 0.4 on all the factors and were removed from the data. Eight items cross-loaded (loadings > 0.3) on two factors and were removed: "I have better clarity about my responsibilities as an engineering educator" (The teaching-learning process), "The quality of my lectures has improved substantially" (Course design and delivery), "I can successfully develop good rapport with my students" (Creating a dynamic classroom), "I can video record lectures and upload them on you tube" (Harnessing the power of technology), "I can create a course website using free resources like Canvas, Google Classroom, Edmodo, etc." (Harnessing the power of technology), "I can effectively use virtual labs in laboratory courses" (Harnessing the power of technology), "I can effectively implement collaborative activities with my students" (Collaborative learning), and "I can deal with unethical practices during assessments" (Effective assessment). One item cross-loaded on three factors and was removed: "I can design my course using backward design" (Course design and delivery). Five items were deleted as they had different focus than most of the items in that factor.

The final factor structure with the list of items in each factor and factor loadings is presented in Table 4. The items in each factor are sorted in decreasing order of the factor loadings. The factor loadings for the first factor range from 0.67 to 0.81, the second factor from 0.75 to 0.81, the third factor from 0.52 to 0.75, the fourth factor from 0.43 to 0.81, the fifth factor from 0.42 to 0.77, and the sixth factor from 0.55 to 0.90. The Cronbach's α (coefficients of internal consistency reliability) for the six factors ranged from 0.82 to 0.87. Table 3 shows the mean and standard deviations of the questions on the survey related to performance and professional confidence of IIEECP certified faculty members. Like the other survey items, the participants responded to these questions on a five-point Likert scale. The average values of

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the self-reported scores by the faculty respondents on all the six prompts presented in Table 3 are more than four (out of five). This indicates that most of the faculty members who completed the IIEECP has shown improved performance and professional confidence.

Table 4: Final factor loadings of the IIEECP survey instrument

#	Category	F1	F2	F3	F4	F5	F6
	The Teaching-Learning Process (Cronbach's α=0.85)						
1	I have been sensitized about my role in keeping my students engaged and motivated	0.81					
2	I can use major theories of learning in teaching my courses	0.77					
3	I can define major theories of learning required in teaching my courses	0.74					
4	I can compose my teaching philosophy statement	0.73					
5	I can identify my short and long-term professional goals	0.67					
	Course Design and Delivery (Cronbach's α=0.82)						
6	I can plan an independent study program which helps me to complete my course in time		0.81				
7	I can implement an independent study program which helps me to complete my course in time		0.80				
8	I can implement a flipped class		0.76				
9	I can plan a flipped class		0.75				
	Creating a Dynamic Classroom (Cronbach's α=0.85)						
10	I can successfully manage students with disruptive behavior			0.75			
11	I can predict students with disruptive behaviour			0.61			
12	I can plan my office hour effectively for individual and small group meetings			0.52			
	Harnessing the Power of Technology (Cronbach's α=0.87)						
13	I can effectively incorporate virtual labs in lectures				0.81		
14	I can effectively integrate MOOCs in my courses				0.51		
15	I can deliver online classes effectively				0.43		
	Collaborative Learning (Cronbach's α=0.85)						
16	I can create instruments for evaluating individual performance in a collaborative activity					0.77	
17	I can create instruments for evaluating group performance in a collaborative activity					0.74	
18	I can plan effective collaborative activities for my course					0.42	
	Effective Assessment (Cronbach's α=0.84)						
19	I can deal with plagiarism practices during assessments						0.90
20	I can create effective rubrics for class assignments						0.83
21	I can create effective rubrics for class projects						0.68
22	I can create good question papers for tests and exams						0.66
23	I can create good open-book tests/exams						0.55

Table 3: Descriptive Statistics of Performance and Professional Confidence

#	Prompts	Mean	SD
1	After using the strategies learnt in IIEECP, my student rating has improved	4.14	0.79
2	After being sensitized by IIEECP, my rapport with the students in class has improved	4.24	0.78
3	After being sensitized by IIEECP, my rapport with the students outside the class has improved	4.20	0.81
4	After completing IIEECP, my confidence to take on leadership role in the department has increased	4.28	0.77
5	After completing IIEECP, my professional confidence in interacting with the industry has increased	4.10	0.84
6	After completing IIEECP, my professional confidence in interacting with the engineering community has increased	4.23	0.78

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Conclusions

In this paper, a survey instrument was designed to measure the competencies, skills and professional confidence acquired by Indian engineering faculty through the IIEECP. The instrument was designed on the basis of the specified outcomes for each of the six modules of the certification program. An exploratory factor analysis was conducted to determine the factor structure and it resulted in six factors aligned with the six modules of the certification program. The internal consistency reliability of the six factors was checked using the Cronbach's α.

The instrument was found to be effective in measuring the target skills and professional confidence. The study brings some valuable outcomes for engineering education in India. To begin with it provides a framework around which engineering institutions can develop their own criteria for faculty evaluation. It allows a better understanding of faculty training needs and how to address them. The instrument will serve as a practical tool for faculty to self-reflect and assess their own competencies as well as their learning needs. Finally, the survey instrument provides invaluable feedback to the IIEECP team to assess the strength and weaknesses of different modules, and to further reinforce the program.

One of the limitations of this work is that the evidence for content validity was not collected. Hence, in a future version, the instrument can be further improved by collecting evidence from the expert team teaching and evaluating each module. Investigating the influence of participants' demographic variables on all the six modules is another direction for future work. A follow-up qualitative study is planned to investigate the beliefs and perceptions of the certified faculty members to understand changes in their personal and professional growth after completing the certification.

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