A Developmental Framework for Teaching Expertise for Engineering and Related Disciplines

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***Abstract*— Many universities, faculties and departments provide training and education to its new and existing faculty in pedagogical areas. Many are informal and internal courses, workshops and seminars, a few are more formal and recognized initiatives like the US National Effective Teaching Institutes established by Richard Felder and Rebecca Brent. This paper describes one of the latter programs – the one that has been developed by InnovaHiEd (www.innovahied.com) – which focuses on training engineering and other disciplines professors in obtaining the recognized International Engineering Educator Certification granted by IGIP (International Society for Engineering Pedagogy – www.igip.org). It is called the International Engineering Educator Certification Program (IEECP). This paper includes a description of its novel curriculum, its developmental framework for teaching expertise, the student learning experiences, its assessment strategy as well as the learning outcomes of the first cohort offered in 2017. The program and framework presented can help universities interested in developing and demonstrating teaching expertise among its faculty.**

Keywords—engineering education; STEAM; STEM; faculty development; teaching expertise; teaching/learning methods; IGIP; InnovaHiEd

I. INTRODUCTION

Faculty development is defined as "a set of activities that engages all members of the teaching faculty in the kind of continuous professional development that enhances their ability to construct curricula and modes of instruction that more effectively fulfill the educational mission of the institution and the educational needs of students and society." [1]. In the last decade, research shows that faculty development programs have been growing globally [2]. Given the broad changes in accreditation criteria in engineering and STEM/STEAM[1] higher education during the last 20 years, faculty development programs have become especially important. Accreditation criteria like that of ABET and the Washington Accord [3] and EUR-ACE in Europe [4] are requiring programs to be outcomes-based, faculty to develop competencies like teamwork, communication and others that require new teaching methods as well as build and sustain industry-university relationships and outcomes assessment strategies for continuous improvement and have in place a method to ensure quality.

Other significant changes in the higher education ecosystem are demanding change, especially for engineering education. Attraction to engineering and technical degrees is decreasing and there are low graduation rates and high attrition rates. Studies demonstrate that students are not satisfied and comfortable with the outcomes and skills included in these programs. Despite of this, education in STEAM is at the core of economic growth and innovation around the world.

To tackle with this issue, university degrees must renovate by (1) addressing real need outcomes that society demands, (2) defining learning outcomes ([4]competencies) that integrate knowledge, skills and attitudes, and (3) align teaching and assessment procedures to cope with the new graduate's profile. STEM professors and leaders need to be trained in these issues to be able to lead their institutions in better addressing society's needs in the 21st century.

II. ABOUT INNOVAHIED AND IGIP

InnovaHiEd is a consulting and capacity building group established in 2014 consisting of a network of associates that

[1] STEM refers to Science, Technology, Engineering and Mathematics. STEAM refers to STEM and Art + Design

range from professors who have dared to change the way they teach and thus increased their students' learning, to deans who championed major transformations in their colleges, to Silicon Valley entrepreneurs and industry leaders who have nurtured and expanded academic partnerships. It is a group of individuals who have dedicated their lives to improving higher education, especially engineering education, comprised of many world educators with prestigious awards and recognitions. They have transformed themselves, their institutions and higher education – and make themselves available to help others through similar transformations. The group offers capacity building, mentoring and coaching to science, technology, engineering and math educators and leaders in re-engineering curricula, teaching/learning methods, outcomes assessment, building and nurturing industry-university relationships and many other strategic and practical areas in higher education.

In 2016, InnovaHiEd was authorized by the International Society for Engineering Pedagogy (IGIP) [4] to establish a faculty development center to provide training to STEM faculty to obtain IGIP's International Engineering Educator Certification, joining dozens of other centers around the world. Any engineering educator who passes the curriculum at any accredited training center for International Engineering Education, and whose education, training and professional experience meet the IGIP standards may register for the professional register as "International Engineering Educator ING.PAED.IGIP". [4]. InnovaHiEd's capacity building program is called The **International Engineering Educator Certification Program (IEECP)** described henceforth.

III. IEECP, INNOVAHIED'S DEVELOPMENTAL FRAMEWORK FOR TEACHING EXPERTISE FOR ENGINEERING AND RELATED DISCIPLINES

A. Curriculum Design and Value Proposition

The IEECP curriculum was developed using a backward design (BA) approach, like the one described by Tamir, Harichandran and Morell [5] and Morell [6]. In BA design, the designer chooses learning outcomes before instructional methods or assessment. This method challenges traditional methods of curriculum planning in which a list of content to be taught is determined, lecturing/labs are the teaching methods, and, homework, quizzes and tests are the usual assessment methods. The developmental framework was adapted from Kenny et al. [7]

IEECP's value proposition for those who pursue the IGIP certification is that they learn by doing. They learn by example. IEECP's instructors are carefully chosen so that they practice what the IEECP curriculum expected outcomes specify. In other words, if we teach outcomes-based curricula, IEECP's curricula must be outcomes based. If we advocate active and authentic teaching/learning, then that is how IEECP modules are taught. If reflection and outcomes assessment are important for STEAM educators, then the IEECP program must provide for reflection (e.g., building a Teaching Portfolio as requirement) and many instances for assessment (student learning, faculty teaching, program evaluation). The IEECP instructors MUST be role models for students in the program. Figure 2 shows some of the characteristics of the program.

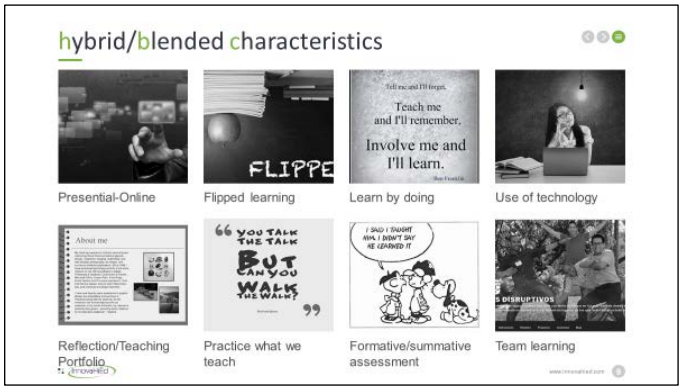
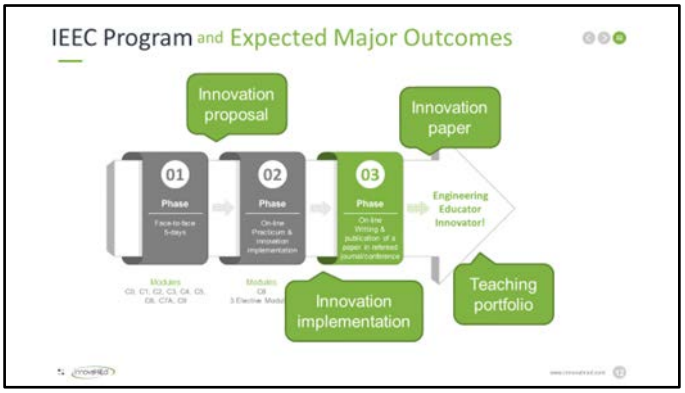


FIGURE 1. IEECP CHARACTERISTICS

B. The IEECP Curriculum

Figure 2 shows the IEECP curriculum. The 20 ECTS[2] cohort-type program, which can be completed in a minimum of eight (8) months, has the following objectives:

- Provide a formal, internationally recognized qualification in teaching and learning methodologies for engineering and related disciplines for faculty, graduate students and other interested parties worldwide.
- Provide fundamental knowledge of the theory, the didactics and the methodology, as well as the best practices of engineering education to become effective teachers and mentors.
- Understand the mission of a university or a technical college and balancing its strategies to better serve constituents.
- Understand the reasons why engineering and related-disciplines' educators need to continuously innovate curricula as well as learning/teaching methods and incorporate outcomes assessment strategies, and,
- Prepare educators in using state-of-the-art technologies for effective teaching, communicating with students and managing courses.



[2] ECTS = European Credit Transfer System.

FIGURE 2. IEECP CURRICULUM AND EXPECTED MAJOR OUTCOMES

At the end of the program, students will be able to:

- Understand and apply fundamental knowledge of the theory, the didactics and the methodology, as well as the best practices of engineering education to become effective teachers and mentors.
- Understand the mission of a university or a technical college and balancing its strategies to better serve constituents.
- Recognize the reasons why engineering and related-disciplines' educators need to continuously innovate curricula as well as learning/teaching methods and incorporate outcomes assessment strategies.
- Apply state-of-the-art technologies for effective teaching, communicating with students and managing courses.
- Understand the fundamentals of student learning and program outcomes assessment and plan outcome-based accreditation for continuous quality improvement.
- Reflect and document teaching and the need for further professional development.

To develop the competencies described above, a series of learning experiences (course modules, team working, forum communication, reflections, practicum, etc.) were designed and distributed in the program's three phases as shown in Figure 2:

1. An intense week of face-to-face of introductory learning activities
2. Online learning and the implementation of a classroom innovation at participants' institutions, and,
3. The publishing of a team innovation paper in a peer-reviewed journal or conference.

Phase 1 is presential (face to face) while Phases 2 and 3 are online. Students are grouped in teams and motivated to communicate with each other to plan, learn and resolve issues.

C. IEECP's Teaching/Learning Methods

The program uses a learner-centric approach, instructors putting themselves in the students' places. Therefore, it is critical to understand the learners' history and their learning styles preferences. A pre-program questionnaire to understand students' prior experiences in relation to the competencies addressed in the program and the Felder and Silverman Learning Styles Model. [8] test is carried on before the start of the program.

The approach to selecting IEECP's teaching/learning methods is as follows:

- Learner centric – instructors are motivated to "put themselves in the shoes of the student". Many of the students in the program are learning new methods for the first time, while others maybe using them for years.
- Learn by doing – as deemed proper, the instructors must use teaching/learning methods that are being shared the in the program ("walking the talk"). In this way students experiment some of the teaching/learning methods they can use in their classrooms.
- Be flexible – if one teaching/learning method is not working, try another. Both learners and teachers need to be aware that learning is a process, that there are multiple ways of teaching and that all are involved in a continuous learning process. New methods will be tried. In addition, the whole purpose of teaching is learning, therefore, all need to be aware that barriers do exist, and unpredictable situations arise, and we need to be flexible and adaptive.

Enjoy learning – if the learner and the teacher are not enjoying themselves, learning does not occur. Celebrate successes and accept failures as part of the learning process.

These methods need to be understood and practiced by instructors, thereby, all instructors are required to complete the IEECP in order to obtain the IGIP's certification.

D. Relationship with Peace Engineering

The title of WEEF 2018, the international conference wherein this paper is proposed to be presented, is Peace Engineering. As defined on its website [9], "*peace engineering is the application of science and engineering principles to promote and support peace. It's the system-level thinking that engineers do that is required to solve global, challenging and audacious problems, like peace*". The authors of this paper believe that if STEAM faculty are duly trained on pedagogy themes, like the ones addressed by the IEECP, and they become role models to students they, in turn, will acquire the necessary engineering competencies to tackle with not only engineering challenges and opportunities, but apply those skills and values to engineer peace and successful negotiations that benefit humanity may that be in their own life situations but also at their jobs, communities, countries and, yes, in the world.

E. Program Outcomes Assessment

The Program evaluates its outcomes in all dimensions: student learning, faculty performance, achievement of program outcomes. The overall outcomes assessment strategy is shared to students in the Learning Management System (LMS). There are student's self-assessments, peer assessments (both internal and external to the program), reflections, faculty-student evaluations, student-faculty evaluations and many more. Figure 3 shows an overview of the assessment dimensions.

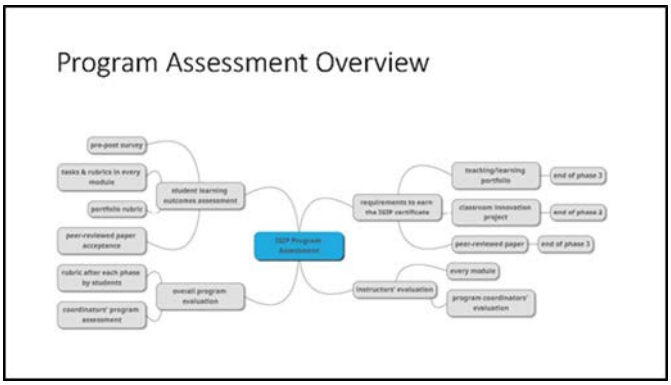


FIGURE 3. IEECP OUTCOMES ASSESSMENT STRATEGY

F. Alignment of IEECP and IGIP Curricula

While IGIP provides centers with the minimum curriculum content for the faculty development programs, in approving InnovaHiEd curriculum it demonstrated the organization promotes innovation and creativity as long the programs achieve its objectives. Table 1 shows the IGIP approved InnovaHiEd curriculum and its alginment with the IGIP curriculum.

Modules	Alignment with IGIP Program	ECTS
Core Modules (required)		
C0 – Fundamentals of IT for Course Management	ICT, E-Learning	2
C1 - The Need to Innovate Engineering Education	Sociology	1
C2 - Fundamentals of Outcomes Based Curriculum Development	Engineering Education in Theory	1
C3 - Teaching Methods and Active Learning Structures to Develop Competencies	Engineering Education in Practice, Laboratory Didactics, Psychology, Creative Thinking, Intercultural Competencies	1
Theory Modules (required)		
C4 - Fundamentals of Outcomes Assessment	Evaluation of Student Performance, Assessment Techniques	1
C8 – Integrating Ethics Across the Curriculum	Psychology, Sociology	1
Practice Modules (required)		
C5 - Harnessing Technology in Higher Education	ICT, E-Learning	1
C6 - Faculty Communication Competencies	Psychology, Sociology, Engineering Education in Theory & Practice	1
C9 - Teaching/Mentoring Practice (Teaching Clinic)	Engineering Education in Practice	1
Electives (to choose 3)		
E1 - Outcomes Based Accreditation	Quality management	1
E2- Faculty Evaluation Best Practices[3]	Psychology, Sociology, Coaching & Mentoring	1
E3 - Managing Change in Higher Education	Psychology, Collaborative Work	1
E4- Effective Strategic Planning in Higher Education	Working with Projects, Collaborative Work	1
E5 - Developing and Nurturing Industry-University Collaboration	Intercultural Competencies, Collaborative Work	1
E6 - Integrating and Managing the Research Function[4]	Creative Thinking, Portfolio Assessment	1
E7 - Ecosystems that Promote Innovation & Creativity[5]	Creative Thinking, Working with Projects	1
E8 – Teamwork and How to Teach It	Psychology, Sociology	1
E9 - Retention Best Practices in Engineering Education	Psychology, Engineering Education in Practice, Collaborative Work	1
E10 – Developing Major Design Experience Capstone Projects	Engineering topics, Laboratory Didactics, Working with Projects, Assessment Techniques, Collaborative Work	1
E11 – Knowledge Management in the Digital Age	Drivers for knowledge management in different industries. KM Processes and Infrastructure, Building KM business case, KM Platform capabilities, KM Program proposal develop as a team project and team presentation, KM Implementation strategies and KM Maturity assessment	1
E12 - Introduction to Design Thinking	Creative Thinking, Working with Projects, Engineering Education in Practice, Collaborative Work	1
E13 - Understanding the Power of Big Data	Big data concepts, real world big data problems, big data technologies, data mining techniques, data visualization, data privacy and security, applications	1
Project (required)		
C7A - Final Project – Becoming an Education Innovator	Working with Projects, Engineering Education in Practice, Collaborative Work	2
C7B - Final Project - Becoming an Education Innovator	Working with Projects, Engineering Education in Practice, Assessment Techniques, Scientific Writing, Presentation Skills, Collaborative Work	5

Blue = Phase 1; Yellow = Phase 2; Green = Phase 3

TABLE 1. ALIGNMENT OF INNOVAHIED AND IGIP CURRICULA

All in all, it takes a total of 500 hours for the students to learn the Program's competencies, as described in Table 2 (considering that a student can devote between 12 and 15 hours per week for non-presential learning activities).

Due to paper length limitations, description of individual courses/modules cannot be included in this paper. In lieu, authors have chosen to share the outcomes of the first offering of the program (2017 Cohort).

Phase	ECTS	Presential learning hours	Other learning (online, team & self-learning, project-based learning, etc.)	TOTAL
1	11	40 (1 week)	235 (16 weeks)	275
2	4		100 (8 weeks)	100
3	5		125 (10 weeks)	125
TOTAL	20	40 (1 week)	460 (34 weeks)	500

TABLE 2. IEECP SCHEDULE AND TEACHING MODALITIES

[3, 4, 5] In development

IV. Outcomes of The First Cohort Experience - 2017

The first offering of the program was kicked off on January of 2017 with twenty-six (26) very motivated participants (deans and faculty leaders) from Argentina, Chile, Costa Rica, Dominican Republic, Perú and Puerto Rico and hosted by the University of Puerto Rico – Mayagüez Campus (UPRM) Cohemis Center [9] in collaboration with the International Federation of Engineering Education Societies (IFEES) [10], Harvard University's Laspau Center [11] and the Research Center for Innovation in Education [12]. See Figure 4.

A. Who were the students – the Cohort Profile

Some of the attendees were driven to the program by curriculum and teaching innovations already in motion at their institutions and wanted to incorporate new approaches and trends (for example, outcomes-based education, flipped learning), others were moved to attend to initiate change at their institutions. The motivation to participate was grouped in three major areas: innovation, improvement and the development of faculty training programs. 71% of the participants were motivated by their intention to improve courses or curriculum, 17% were interested in designing faculty development programs at their institutions, and 8% were interested in performing innovation. 4% of the participants were motivated by the reputation of the program.

Figure 4. Students and Instructors of the First Cohort, January 2017.

Several institutions brought teams of colleagues who were eager to learn from others and from instructors' experiences. Two of the IEECP instructors also registered as participants to earn the academic certification, making a grand total of 26 students. The participants represented an interdisciplinary population where 70% were from engineering, 30% from STEAM and half of them have less than 10 years of teaching experience. Less than 35% of the faculty had experiences using active learning or cooperative learning as part of their teaching strategies, even though 67% indicated having educational training through courses or workshops and only 13% participated in engineering education-focused conferences. Participants ranked their pedagogical knowledge using a scale of 1 = low to 5 = high, the average of this cohort ranked their educational knowledge at an intermediate level of 3.

Figure 5 shows a predominance of active, sensorial, sequential and visual learners in the population. However, all learning styles were present requiring a diverse portfolio of teaching activities to address this learning style diversity.

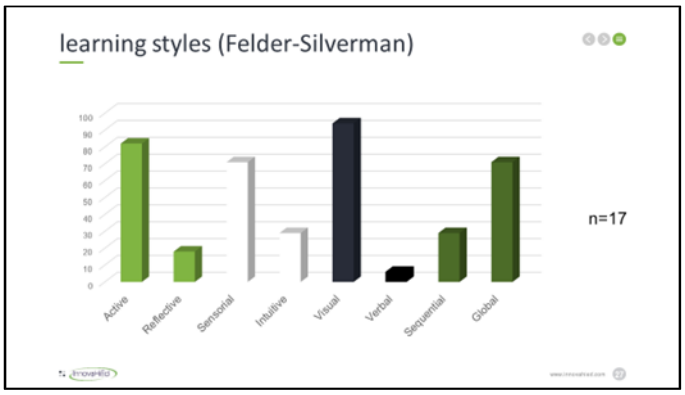


Figure 5. Cohort Learning Styles (Felder-Silverman)

All students in the 2017 Cohort completed satisfactorily the IEECP requirements obtained the IGIP.ING.PAED academic title.

B. Student's Assessment of Instructors

Students evaluation of instructors' teaching reflected an extraordinary performance of teaching. As can be seen in Figure 6 and comments made by students, the Program satisfied their expectations.

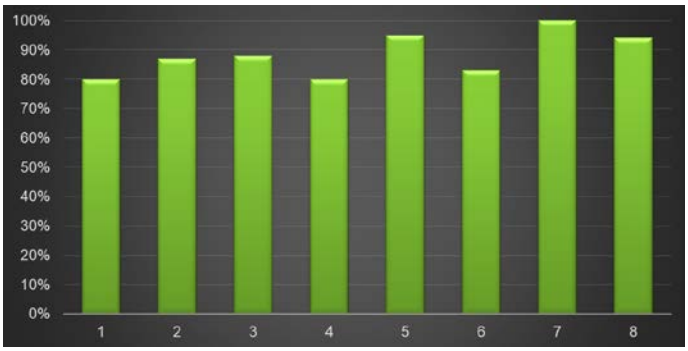


Figure 6. Students Evaluation of Instructors

"The program surpassed my expectations"

"I am very satisfied because the program addresses many of my worries and provides answers to barriers I had observed in my teaching practice"

"I like how the [the program] provides for building relationships with colleagues and instructors"

V. Lessons Learned

What did we learn from the first cohort offering?

Some Positive Lessons

- Program content and its organization was well received by students.
- The use of flipped learning was successful for both students and instructors.
- Instructors' enthusiasm is contagious – keep it up!
- Virtual Campus (Moodle) is an asset for this kind of program implementation.
- Importance of good internet connection for face-to-face and virtual meetings.
- Communication among instructors is vital.
- Asking students to work in teams and giving teams a name.

Things that Can be Enhanced and are being Implemented in the 2nd Cohort of 2018

- Not enough time was allocated for each module.
- Some modules required too much work.
- Teamwork module has to be offered early on in the course.
- Intention of having final papers written in English not realistic
- Coordination and linking of modules' tasks.
- Content and length of some modules' videos.

VI. Conclusions and Future Research

An outcomes-based STEAM faculty development program has been designed and implemented by InnovaHiEd. The IEECP complies with the IGIP ING.PAED academic certification. The first cohort of the program was conducted in January of 2017 with 26 students, all of which earned the Ing. Paed.IGIP certification and were very satisfied with the program. Future research and papers will include IEECP curriculum modules description and outcomes, the use and application of technologies for teaching as well as outcomes on innovations integrated into the program.

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