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Continuing engineering education: a needs assessment for the introduction of a graduate certificate programme

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ABSTRACT: The article presents the results of a survey to determine the interest in the graduate certificate programme in engineering education. The survey included queries regarding the need for training in general, preferred areas of training, preferences in the type of professional development programme, its duration, delivery method and other important related issues. The survey was sent to human resource representatives from industry and from academic institutions across the United States of America. There were 191 responses to the survey: 86 from industry and 105 from academic institutions. The results obtained clearly indicate the need and preferences related to the content area and pedagogical framework of the programme. The information is currently used in the preparation of the on-line graduate certificate programme in engineering education.

Keywords: Engineering education, continuing professional development, graduate certificate

INTRODUCTION

Teaching in general can be considered as a science subject although it certainly has a certain degree of creative art. That art, apart from some degree of talent and compassion, also requires certain skills. Artists, such as painters or sculptures need to learn their craft, and the same applies to instructors who also need to learn certain skills to be able to choose the tools, materials and methods of their trade.

However, university lecturers and industry or community college instructors employed to teach engineering are usually expected to acquire teaching skills without any formal preparation for educational functions. From the authors' extensive academic experience and from numerous discussions with local and foreign colleagues, it is certain that instructors in engineering programmes at most levels are rarely prepared for educational challenges.

The practice in many institutions is to offer a newly employed instructor a short teaching or training programme, normally organised by the employer. Such an induction programme is the only theoretical educational exposure, which they receive in terms of pedagogy (i.e. assessment, curriculum design, teaching and learning practices) that must suffice for the duration of the career of the new recruit as an engineering educator.

It is obvious that a faculty member will base his or her teaching style on personal experience (e.g. how he or she was previously thought) and possibly improve it *on the way* by delivering courses and employing some educational tools and methods. Most instructors consider themselves to be engineers, researchers or scientists rather than teachers. They also consider the need of any change in their teaching in the form of change in the content and not in their role as teachers playing a vital role in the learners' learning. The developments in technical fields do find the way to the classrooms; however, the new pedagogy and the developments in teaching and learning are normally forgotten or even not considered to be of importance [1].

It is only in recent years that the culture of engineering education has changed, which has led to the emergence of engineering education as a new multi-interdisciplinary field of study (and a standalone departmental governed unit) within a college of engineering in many institutions in the United States [2]. Furthermore, historically, teaching practices and beliefs held by faculty members in higher education have largely been anecdotal [3]. The change was brought by a call for a transformation of how engineering is being taught.

Typically, the undergraduate degrees in engineering education are not offered. That is not a surprise as for the engineering educators to be successful, they have to possess not only fundamental, but also specialised knowledge in any of the engineering disciplines. It is a common understanding and agreement, although not written, that the engineering degree must come first in the professional path of an engineering instructor.

The programmes offered in the area of engineering education are mainly postgraduate programmes at the level of PhD and Masters or certificate programmes [2]. And the concept of the need of engineering knowledge prior to engineering education expertise is emphasised by postgraduate programmes in engineering education requiring a Bachelor's and/or Master's degree in an engineering discipline or embedding the specialisation within the graduate course requirements. Such requirements are only logical if, indeed, the engineering instructors are to satisfy the accreditation requirements of an engineering discipline.

However, postgraduate degrees at the level of PhD or Master's in engineering education have the aim of not only preparing a graduate to actually teach, but maybe even more importantly, to conduct and direct research in the area of engineering education. The programmes, which directly educate learners in the theory and application of engineering education, are graduate (or postgraduate) certificates.

Certificate programmes have grown in popularity especially for professionals with time and financial limitations, and many universities offer such programmes in areas such as business, education, health care and technology [4]. In recent years, such programmes also acquired a better recognition and understanding of their value and changed the original negative comprehension of certificate programmes [5].

A certificate programme is a form of educational training, which gives the graduates a certificate of completion and not a degree [6]. The certificate programmes, which are an obvious element of continuing education, are used by candidates to improve their competitiveness in the labour market and serve as a valuable addition to an ordinary degree. They are also useful in assisting quick upgrading of knowledge and skills in a particular area of interest, a career change or enhancement in a specific already-acquired job.

Such programmes, which are much shorter than programmes culminating in a degree, normally offer much more flexibility to learners and provide a cheaper way of acquiring additional knowledge. They can also become a first step in acquiring higher degrees, especially when some courses' articulation can be applied. A large number of certificate programmes have been offered in a distance education mode providing to the learners' flexibility in schedules and extending access to courses. Although, at the moment, most of certificate programmes are offered in face-to-face mode, the majority offer or are planning to start classes on-line [6].

The flexibility of certificate programmes extends also to universities, as the conditions to initiate such programmes are less rigid than for degree programmes [4]. Although assessment and management, as crucial to academic integrity of a certificate programme, have to be monitored and documented carefully prior to, during, and following programme implementation, the bureaucratic burden of such programmes is still less than for typical degree programmes, especially, professional programmes. Programmes of that type can also be part of the recruitment strategy of a department/ college to higher degrees.

The certificate programmes are also considered to be a considerable source of revenue for the departments, despite the university management retaining some of its revenue. The financial issues related to certificate programmes have become more complex and important from the moment of emergence of for-profit education institutions [7].

Certificate programmes are increasingly in demand as they offer an opportunity to develop specific skills and additional knowledge, especially in specialised areas not necessarily related to the original educational background of the learners. Such programmes are a viable source of continuing education, improving the competitiveness of the graduates on the market [8].

As mentioned before, a lack of pedagogical education of many instructors severely impacts teaching and learning in engineering programmes [9]. That applies equality to degrees offered at universities, community colleges and engineering trainers working in industry. The on-job training is obviously not satisfactory to become a skilled engineering instructor.

On-line mode of delivery is one of the most convenient instructional approach, which has steadily grown in popularity, to the point that in the fall of 2015, almost one-third of US post-secondary learners were taking at least one on-line course [10]. An on-line course is defined as one in which at least 80% of the course content is delivered on-line and provides learners with the flexibility in time and place of learning following the concept of *anywhere, anytime* [11]. It also allows a learner to work at a personal pace with less academic pressure, as well as enables learners the time to examine an issue before responding [12].

Those advantages are related to asynchronous communication mode, with their own challenges, such as miscommunication, isolation and lack of interactions. A synchronous approach, which may provide learners and

instructors with better affective experience, introduces challenges related to different time zones for distant geographical places, technical problems related to delays, breaking in communication, so crucial with any real-time event. The synchronous component of the on-line learning offers personal touch of the learning experience through live interactions with the teachers and fellow learners.

The Department of Engineering Education of the College of Engineering at Utah State University, for some time considered an idea to offer other than a PhD programme currently offered, which would complement its offering in the area of engineering education. The programme was also to benefit the engineering professionals and educators by providing an educational programme to advance their educational knowledge and skills. The programme was also to add value to employers by preparing their employees to become more effective engineering educators/trainers, leaders and educational managers. In order to assess potential interest and to sense the type of programme, which would be attractive to potential candidates, a survey was sent to academic institutions and industry to determine the most suitable programme.

MATERIALS AND METHOD

In order to determine the need for an engineering education professional development programme, a needs assessment survey was developed and conducted. An invitation to participate in a survey was sent out via e-mail to organisations involved in engineering training, such academic institutions and industry. The survey constituted a need assessment tool, which was part of strategic plan developed to guide the activities related to the introduction of the new programme. The questionnaire that was developed contained 21 questions organised in five specific areas:

1. Organisational profile of the respondent;
2. Interest in particular type and duration of programme (doctorate, Masters, certificate);
3. Preferences for type of learning delivery method;
4. Interest in specific content areas;
5. Limitations, challenges and/or features important to the respondents.

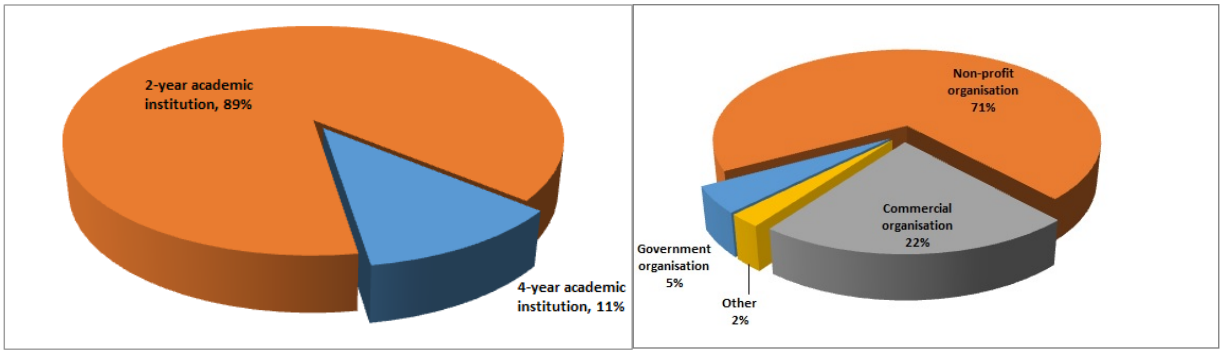
The survey was sent with a cover letter explaining the reason for seeking the information and inviting participation in the survey. It was sent to human resource representatives from industry and from academic institutions in the United States. A total of 191 organisations responded to the survey out of 842 invitations (162 academic institutions and 680 industry organisations involved in the training of engineers). The results of the needs assessment will be used to guide future action.

SURVEY RESULTS

The results presented are based on replies from representatives of invited organisations. The organisations selected were mainly those with a relatively high number of employees involved in engineering teaching and training. However, not all the respondents replied to all questions in the survey, hence the number of answers varies for different questions, as indicated in the figures.

Organisational Profiles

There were 191 responses to the survey; 86 from industry and 105 from academic institutions. The type of organisations, which responded to the survey, is presented in Figure 1.



a) b)

Figure 1: Type of organisations: a) academic institutions; and b) industry.

The majority of respondents, both in academia and industry, had more than 500 employees (67% for industry and 46% for academic institutions, see Figure 2). In terms of location, most of industry subjects came from the West (85%) with no much spread, whereas for academia the range was more even, with a slight majority originating in the Northeast (30%); Figure 3.

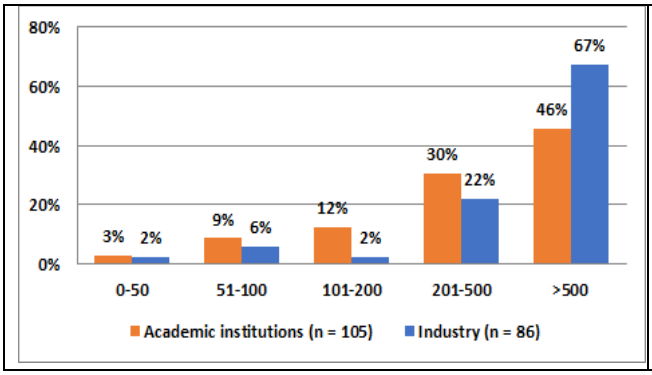


Figure 2: Number of employees in organisation.

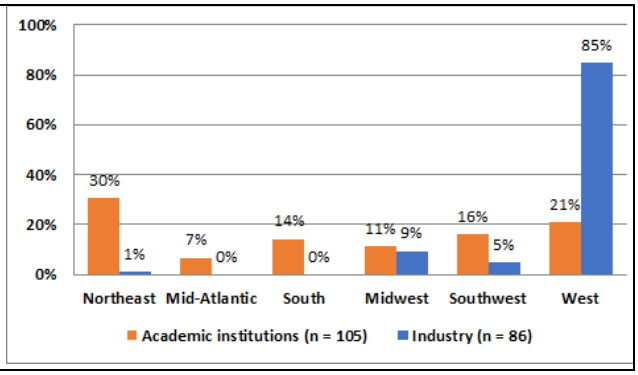


Figure 3: Regional location of organisation.

As designed, the number of employees actively involved in engineering and technology was high for both types of organisation and was typically more than five (Figure 4) with academic institutions having more than 69% of employees having actual training or teaching responsibilities (Figure 5).

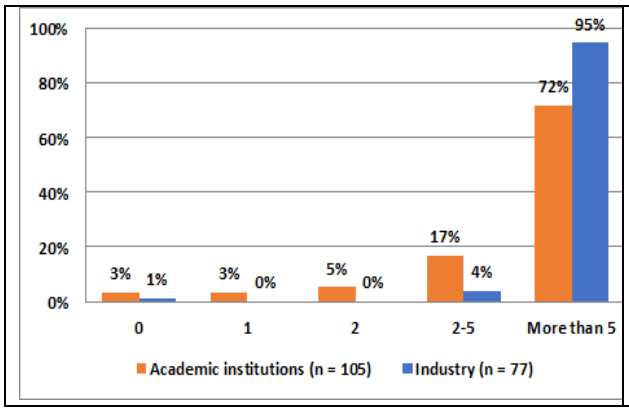


Figure 4: Number of employees actively working in engineering or technology-related areas in organisation.

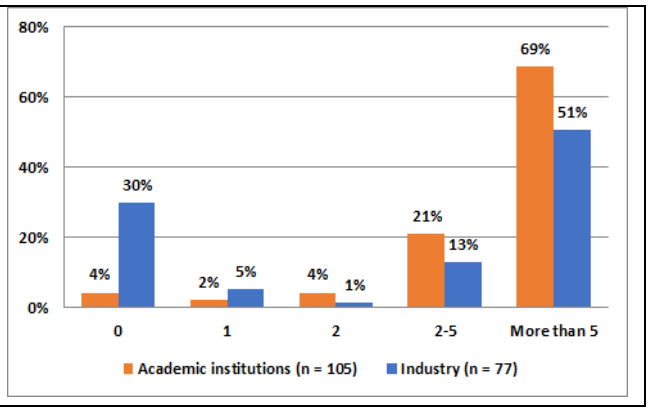


Figure 5: Number of employees actively working in engineering or technology-related areas with specific training or teaching responsibilities in organisation.

Professional Development Programme Preference

The survey included questions related to the preferences regarding the type of professional development programme and its length. The results vary, but the certificate programme (of 12 credit hours) was the most favoured and almost the same for both types of organisation, reaching an average of 47% for both choices (Figure 6).

There were, however, considerable differences between academic institutions and industry in their willingness to embark on PhD or Master's degrees. Almost 40% of respondents from academic institutions indicated interest in a doctoral programme (38%), whereas such programme was not popular among industry (18%), see Figure 6. In contrast, a Master's degree programme was a more popular choice for industry (40%) than for academia (11%).

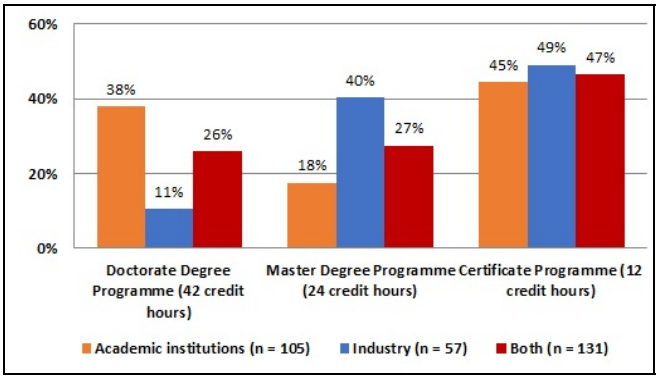


Figure 6: Preference on type of the professional development programme.

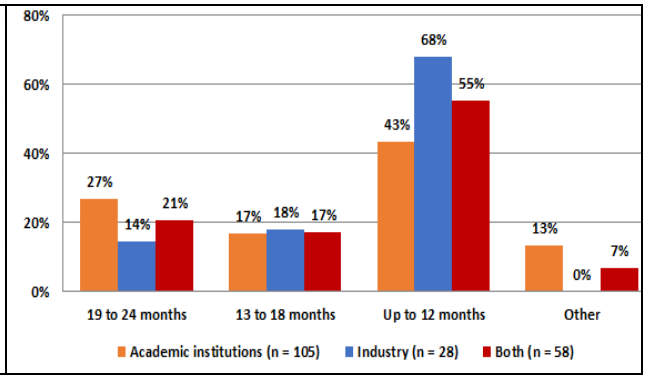


Figure 7: Preference on the length of the certificate programme.

The preference for offering the favourite certificate programme of 12 credits over a period of up to 12 months for both academic institutions (43%) and industry (65%) can be seen Figure 7. The other options listed by the respondents were one month and three to six months, clearly indicating that the duration was an important factor in the selection.

Preferred Delivery Method and Programme Content Emphasis

The survey also asked the participants, which delivery method would be preferred for the planned engineering education professional development programme. The choices offered were face-to-face, on-line asynchronous instruction with no active interaction with the instructor, and asynchronous and synchronous combination with live interaction with the instructor. The preferred delivery method selected was an on-line asynchronous and synchronous combination with live interaction with the instructor. Face-to-face instruction was favoured ahead of on-line instruction with no active interaction with the instructor, which was considered to be undesirable (Figure 8).

The survey requested respondents to rank the training needs for the instructors in terms of the potential programme content. The respondents were asked to rank the four suggested areas of interests (Table 1). The proposed themes were fundamental areas of education considered crucial for engineering educators. There was little difference in the responses between all four areas; all of them scoring between 20% and 30%. However, the fundamental areas, such as curriculum design and principles of teaching and learning are more favourable than the other two. Essentially, equal distribution of the choices shows a real need for training in basic and principal areas of education. It may be concluded that the respondents were lacking knowledge in those subjects.

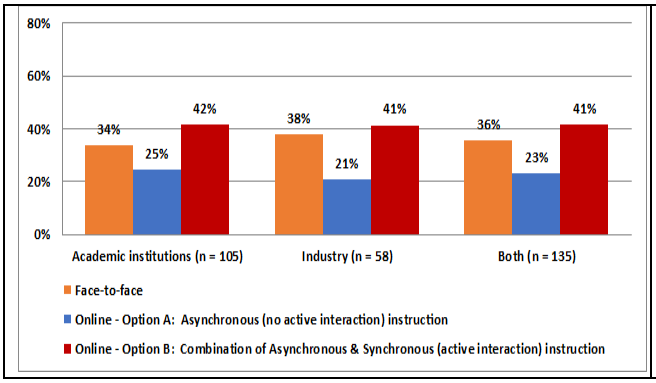


Figure 8: Preference regarding mode of delivery.

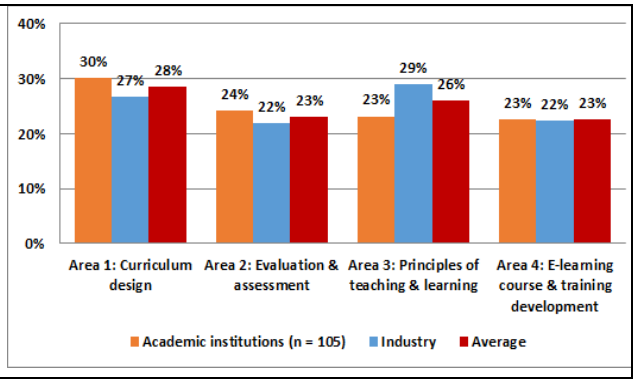


Figure 9: Preference regarding programme content.

Table 1: Programme content areas.

Area 1	Curriculum design: developing educational or training curricula, including the development of learning objectives, and choosing effective teaching methods for learners or learners.
Area 2	Evaluation and assessment: an overview of the various methods used to measure and evaluate learning from a cognitive standpoint.
Area 3	Principles of teaching and learning: learning theories, desirable characteristics, attributes, learning principles, and various instructional/training methods that foster improvement of learning outcomes and skills of a good teacher (or trainer).
Area 4	On-line-learning course and training development: review of learning theories and research for development of on-line teaching and learning modules.

The other suggested topics of interest or needs covered a variety of topics, from more general educational areas to very specific technical subjects, as listed below:

- E-learning, curriculum design;
- CISCO training and IT security training;
- E-learning;
- Statics and strength of materials;
- Software updates new technology;
- Software development mathematics;
- Internet of things (APP development); cybersecurity; virtual reality and augmented reality;
- Case studies and projects: developing and delivering of project-based learning that both offers concrete application of concepts and engages learners with hands-on implementation;
- Testing through hands in projects;
- Statistical analysis of engineering and design.

The submitted topics oddly repeated (not just once) the areas already listed in the survey (on-line-learning and curriculum design) and came up with very particular topics in general engineering (statics, strength of materials, statistical analysis) and computer engineering (CISCO training, IT security training, software updates and developments, Internet of things, cybersecurity). The topics in the general area of education or specific topics in engineering education were very limited to only one topic, namely project based learning. That may indicate the limited awareness of other important areas for engineering educator practice.

Issues Related to Organisation Requirements and Limitations for Professional Training

The respondents from both academia and industry were not clear on the organisations' needs for more engineering instructors. Although the negative response was not predominant (on average 16%), there was no strong indication on the real need. The *yes* and *not sure* answers were similar, with slightly more positive answers from academic institutions and more uncertain answers from the industry (Figure 10).

In terms of whether the organisation considered participation in the professional development programme, both subjects were rather negative, with more than 60% of respondents from academia giving a negative answer. Industry was a bit more positive in giving half-favourable and half-unfavourable replies (Figure 11). There were follow-up questions regarding important features and challenges in respect of the organisation's participation in the professional development programme.

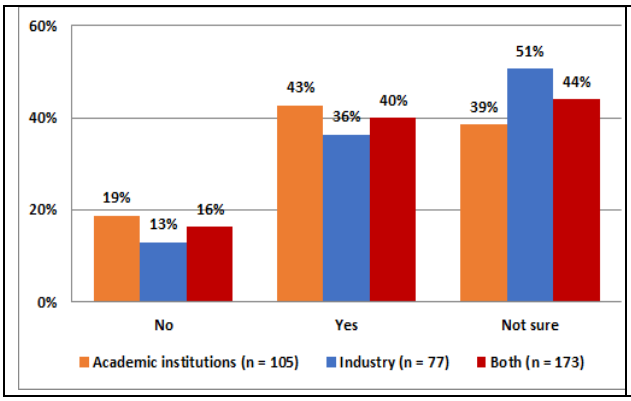


Figure 10: Need for more trainers, faculty members, teachers or staff actively working in engineering, computer and technology-related fields in organisation.

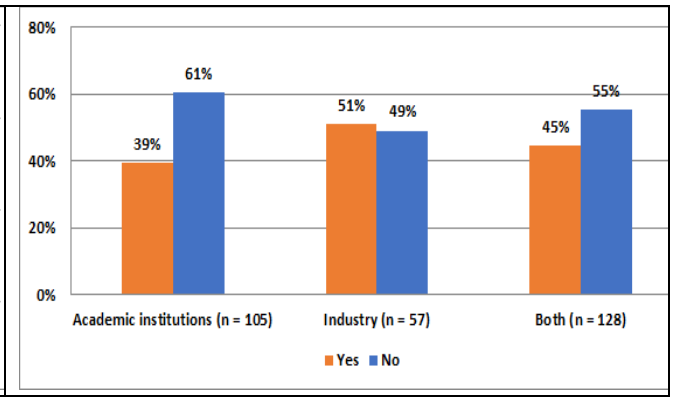


Figure 11: Organisation readiness regarding participation in the professional development programme.

In both cases, features (Figure 12) and challenges (Figure 13), the most important appeared to be the cost and the relevancy of topics. Duration, maybe surprisingly, was not listed as a major factor scoring for both types of organisations the lowest, despite previous answers suggesting short programmes of 3-6 months or even one-month duration was favourably voiced.

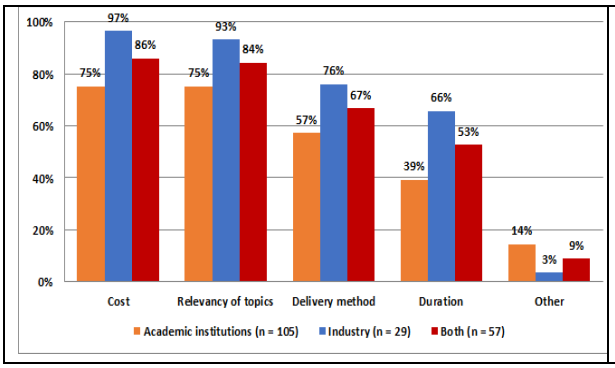


Figure 12: Features of the professional development programme identified as important for organisation.

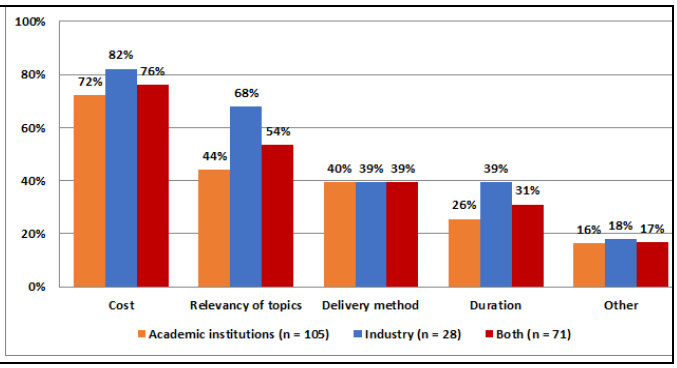


Figure 13: Features of the professional development programme identified as challenges for organisation.

DISCUSSION

The deficiency in pedagogical preparation is widely acknowledged as a serious factor hindering the teaching and learning process of learners. That was the aspiration to investigate the possibility to mount a professional development programme in engineering education for practicing engineering instructors. The survey was prepared as a tool to identify the preferences of potential participants in the programme from academic institutions and industry. The survey indicated several preferred choices for the type of the programme, its duration, content and delivery method.

The survey indicated preference for a certificate programme, of up to one-year duration, compared with a typical postgraduate doctoral or Master's programme. Other implications from the survey specified fully on-line programme, although with active interactions with the instructor(s), containing the fundamental areas in education. Although the age of the respondents was not considered, it was expected that the subjects of the survey came from a wide age span. Judging by the number of responses, a rather large group seemed to recognise personal learning needs that could be met by a professional development programme. That indicates their need for continuing education and the content of the programme should inevitably foster its participants as life-long learners.

Financial issues related to the preparation and running of a professional development programme are both important and, unfortunately, unavoidable. Programme fees depend on the total cost incurred in both the development (initial cost) and delivery (recurrent cost) of the programme. Those fees should be attractive to learners and should bring certain benefits to the department.

Based on the survey conducted, a one-year on-line engineering education graduate certificate programme is currently being developed by the Department of Engineering Education at Utah State University [13]. The programme targets current and future engineering educators and trainers, both in academia (community colleges and universities) and industry. It is intended to be accessible worldwide, and it is anticipated that it would give engineering educators an opportunity to broadly apply evidence-based practices into their workplace or learning environments.

CONCLUSIONS

The survey clearly indicated the need for a professional development programme in engineering education. A number of people responding to questions showed their willingness to participate and also showed their preferred choices regarding the programme. The development and actual offering of such a programme offers both opportunities and challenges.

The main opportunity is the provision of a development programme to professionals in actual need of training. In order to run smoothly, it should also be a prospect for faculty member incentives and income for the department. The challenges, however, most likely overcome the opportunities. The major tasks are related to faculty members' engagement, preparation of the courses, special types of material for on-line delivery, and continued effective running of the programme with financial stability and sustainability.

Launching a graduate certificate programme in response to the needs of the engineering education practitioners in community colleges, universities and industry would require numerous well-planned steps, or more adequately, a strategic plan with survey being just the initial step. To fulfil the promise for an effective and efficient offering of the programme, several next steps have to be addressed and developed. These include the following:

- recruit experienced and flexible faculty members to be involved in the programme;
- prepare a well-constructed professional development programme with four major courses covering four fundamental areas of education, with special consideration for engineering education;
- prepare material in all four major areas suitable for on-line delivery (pedagogy and technology-related aspects);
- guide the programme through the approval process at the university where it is to be offered;
- secure funding for the initial stage of the programme;
- market successfully the programme to provide its financial stability;
- develop procedures to ensure programme quality and continuous improvement.

An on-line professional development programme in the form of a graduate certificate should help to overcome the shortcomings of the existing traditional postgraduate programmes in engineering education. In order for the programme to be launched and to run successfully, it must receive appropriate attention and initial resources, both in terms of finance and faculty member time and devotion. The detailed, although flexible, pursuing of the initial strategic plan will be crucial in the realisation of the programme.

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BIOGRAPHIES

Oenardi Lawanto is an Associate Professor in the Department of Engineering Education at Utah State University, USA. He received his BSEE from Iowa State University, his MSEE from the University of Dayton and his PhD from the University of Illinois at Urbana-Champaign. Before coming to Utah State, Dr Lawanto taught and held several administrative positions at one large private university in Indonesia. He has developed and delivered numerous international workshops on student-cantered learning and on-line learning-related topics during his service. Dr Lawanto's research interests include cognition, learning and instruction, and on-line learning.

Jacek Uziak is a Professor in the Department of Mechanical Engineering of the University of Botswana. He received his MSc in mechanical engineering from the AGH University of Technology in Krakow, Poland, and his PhD in Technical Sciences from the University of Life Sciences in Lublin, Poland. For the past 35 years he has been working at universities mainly in Poland and Botswana; his career includes teaching and research assignments also in Canada, Czech Republic, Norway, UK, Netherlands, France, Germany and the USA. He specialises in engineering mechanics and teaches courses in this area. He has a particular interest in engineering education.

Idalis Villanueva is an Assistant Professor in the Department of Engineering Education at Utah State University. She has a PhD in chemical and biological engineering and a postdoctoral degree in analytical cell biology. She transitioned into engineering education a few years ago and last year, she became the 2017 NSF CAREER award recipient, one of the organisation's highest honours in support of junior faculty who exemplify the role of teacher-scholars. Her research grant will help her and her team of researchers to have a better understanding of the effects of *hidden curricula* in engineering programmes. She also studies academic stress in engineering and makerspaces in engineering, particularly as they relate to academic stress. Both studies are also funded by NSF grants. She recently won the Engineering Education Undergraduate Mentor of the Year Award for assisting engineering students in realising their academic and professional paths.

Melissa Scheaffer is a Principal Lecturer in the Engineering Education Department in the College of Engineering at Utah State University. She has an MS degree in education with an emphasis in adult education, and has taught at the collegiate level for the past 20 years. Her areas of specialty are technical communication and business communication, and she has taught in both the School of Business and College of Engineering. She was hired in the College of Engineering to develop and teach Technical Communication for Engineers, a required course for undergraduates. Her research interests lie in the areas of engineering entrepreneurship and technical documents in the workplace. She recently won the Outstanding Teacher of the Year in Engineering Education and the University Service Award in the College of Engineering.