Implementation of Complex Engineering Problem Solving (CEP) and Complex Engineering Activities (CEA) in Malaysian Engineering Curriculum: A Pilot Study

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2023 International Conference on University Teaching and Learning (InCULT) | 979-8-3503-1574-5/23/$31.00 ©2023 IEEE | DOI: 10.1109/INCULT59088.2023.10482478

Abstract **— Complex problem solving is identified as a top skill required to thrive in the 4th Industrial Revolution, and it is emphasized in the Engineering Accreditation Council (EAC) Standard 12 Graduate Attributes. However, in many cases, engineering programmes lack a clear understanding of the requirements of complex engineering problems, hindering the students' mastery of problem-solving skills for real-world readiness. This paper aims to study the current implementation of complex problem solving (CEP) and complex engineering activities (CEA) in Malaysian engineering programmes. Survey questionnaires were designed to gather feedback from academicians across various institutes of higher learning (IHLs) that offer engineering programmes. The conducted test indicates that the survey instrument is reliable (Cronbach Alpha value of 0.800). The initial findings from a pilot study involving 30 respondents from 10 IHLs show that common courses chosen to address CEP and CEA are the final year project, integrated design project, and other design courses. The majority of CEP and CEA assessments are conducted on a semesterly basis, utilizing project-based assessment. Problem-based learning (PBL) is the most widely chosen teaching and learning strategy, engaging students in solving real-world problems, encouraging active participation, critical thinking, and the application of knowledge. Further research could explore the effectiveness and impact of these teaching and learning strategies on students' learning outcomes, problem-solving abilities, and their abilities to apply CEPS and CEA principles in real-world scenarios.**

Keywords—complex engineering problems skills, complex engineering activities, engineering programmes, assessment tools

I. INTRODUCTION

This paper discusses the implementation of complex engineering problem-solving (CEP) and complex engineering activities (CEA) in Malaysian engineering programmes in the context of the Washington Accord (WA) and Outcome-based Education (OBE) framework. Malaysia became a signatory of the WA in 2019, necessitating the preparation of graduates who can address future technological and societal changes. Under OBE, seven (7) programme outcomes (POs) are emphasized to address CEP and CEA. However, the implementation of OBE with regards to CEP and CEA is still in its early stage. Training on the attributes of complex engineering problems is needed to ensure that the teaching and learning of engineering programmes fulfill the accreditation criteria [1]. In most engineering programmes, it was found that engineering educators often fail to design complex engineering problems to equip the students with the mastery of this skill in preparing them for the workforce [2]. To address this, the study conducted a pilot survey questionnaire among engineering educators from 10 universities to assess the incorporation of CEP and CEA, types of assessments used, weightage, taxonomy level, and departmental support. The study employs a quantitative approach through purposive sampling to gather insights from Malaysian engineering educators.

II. LITERATURE REVIEW

A. Engineering Accreditation Council (EAC) Requirements

The World Economic Forum (2016) and the Ministry of Higher Education, Malaysia identified that complex problem solving is the top skill needed to thrive in the 4th Industrial Revolution [3]. Complex engineering problem solving was emphasized in the International Engineering Alliance's (IEA) programme outcomes [4] and the Engineering Accreditation Council, Malaysia's (EAC) accreditation standard [5]. EAC requires that engineering degree programmes which seek accreditation must prepare graduates for future technological and societal changes, and able to acquire new knowledge through new problems [5]. Due to the importance of this skill, IEA released the attributes of complex engineering problems to guide the signatory countries of the Washington Accord in their implementation of complexity in engineering curriculum in 2013. These attributes can be used by the Higher Learning Institutions (HLIs) to mirror the problems in the classrooms with those in the industry.

B. *Current Implementation of CEPS & CEA in Engineering Programmes in Malaysia*

Realizing the importance of the implementation of CEP and CEA in the curriculums, engineering undergraduate programmes of the HLIs in Malaysia have taken a few approaches to address them. These approaches include problem-based learning and case studies [6], and projects [7]. Although there is lack of evidences of the implementation of CEP and CEA in final examination and test in the HLIs in Malaysia, the finding from previous study showed that the practice does exist in some of the engineering programmes outside Malaysia, for example in the Static Field Theory course at Helsinki University of Technology, Espoo, Finland [8].

Undergraduate engineering programmes in Malaysia are continuously designed with effective incorporation of CEP and CEA to meet the requirements set by the EAC, in addition to ensure that students are well-prepared and equipped with the necessary skills and knowledge for a successful engineering education. Mat Isa et. al. conducted a survey involving 265 engineering educators, and the results indicated that most engineering programmes in Malaysia prioritize the incorporation of CEP within assignments or projects rather than in final examinations or mid-term tests. Alternatively, CEA were integrated into courses such as the Final Year Project, Industrial Training, Integrated Design Project, and laboratory courses in addition to assignments [9]. CEP is also integrated into a SULAM (Service-Learning Malaysia-University for Society) course, which engages students in service and collaborative learning to address complex issues and challenges identified in the society [10].

Designing assessment incorporating CEP and CEA possesses certain challenges among educators to meet a balance between evaluating students' ability to tackle intricate engineering problems and the assessment tool that truly reflects their cognitive skills and understanding. Phang et al. concluded that there is a need for training programmes to equip lecturers with the skills to develop assessments that incorporate complex problem-solving. Their study highlighted that a group of engineering lecturers possessed only a fundamental grasp of complex engineering problems and addressed a restricted range of complex attributes [1]. Liew et al. also found that the engineering educators often struggle to construct complex problems for their courses due to their limited understanding of the complex problems attributes [11].

C. *Teaching and Learning Strategies to Improve the CEP & CEA*

Numerous teaching and learning strategies have been put forth to nurture students' cognitive, behavioural, and personal skills. It is imperative for students to cultivate critical thinking abilities to acquire complex problem-solving skills. Problem- and project-based learning (PBL) are one of the approaches that have proven successful for complex problem learning. Nevertheless, the challenge lies in ensuring the quality of problem-based learning (PBL) and managing the extended student learning time required to solve complex problem [9 -10]. Thus, the project should be carefully designed considering the students learning time invested in solving intricate problems, as well as workload placed on the lecturer.

Practice-related learning and collaborative learning engage the students working related to real-work environment can improve the CPS and CEA, with common learning activities such as internships, industry projects, entrepreneurship, and innovation hubs [12-14]. These learning approaches always include the collaborative work within complex setting and problems, fostering the development of communication and teamwork skills among the students [15]. Other teaching and learning strategies such as questioning techniques, literature review, class discussion, case study etc. in developing critical thinking can be found in [14].

III. METHODOLOGY

A. *Research Design*

A quantitative approach has been utilised for research design in this study by adopting the online survey to collect data from the respondents. The survey was divided into four (4) sections as follows:

Section A: Demographic Profiles of Respondents (name, faculty/school, university, email, designation, administrative post (if relevant).

Section B: Academic Background and Working Experience (Level of education, experience as academician, industrial experience, number of semesters teaching the current taught courses, training programmes attended on complex engineering problems within the programme, number of EAC workshops, number of attended teaching, learning and assessment workshops).

Section C: Strategies in Implementing Complex Engineering Problem Solving (CEP) and Activities in Academic Programmes (courses incorporating CEP & CEA, frequency in assessing CEP & CEA in the programme, mapping of courses to programme outcome with CEP & CEA, Awareness on CEP & CEA characteristics, assessment tools used to address CEP & CEA, Teaching and Learning strategies used to implement CEP & CEA, Teaching and Learning Approaches – Aural, Logical, Physical & Tactical, Social, Verbal, Visual, Solitary, Naturalist, Weightage/Percentage used to include CEP & CEA).

Section D: Recommendation and Continual Quality Improvement (CQI) on the implementation of CEP & CEA throughout the curriculum (method of assessment, suitability of CEP & CEA to achieve the intended outcomes, effectiveness of rubrics used to assess CEP & CEA, CQI at course and programme levels, other recommendations).

This paper presents only six (6) elements that relate to the implementation of CEP and CEA under Section A, B and C as described and discussed in the following section.

IV. RESULT ANALYSIS AND DISCUSSION

This section presents the results and discussion based on the demographic profiles of the 30 respondents for the case study. Most of the survey questions require direct feedback from the respondents. Reliability test was carried out only for 3 questions that require respondents' opinion. The result of Cronbach's Alpha for the 3 item is 0.8 (>0.7 as recommended by Nunally (1970) [16], thus considered as reliable.

A. Demographics

Table I shows the demographics of the survey respondents.

TABLE I. DEMOGRAPHICS OF RESPONDENTS

No.	Demographics	
	Item	***Percentage***
1	**Highest Level of Education**	
	a. Degree	0
	b. Master	13
	c. PhD	87
2	**Years of Experience as Academician**	
	a. Less than 5 years	7
	b. Between 5 to 10 years	16
	c. Between 10 to 15 years	29
	d. Between 15 to 20 years	29
	e. More than 20 years	19
3.	**Years of Experience in Industry**	
	a. None	10
	b. Less than 1 year	26
	c. Between 1 to years	22
	d. Between 2 to 3 years	22
	e. Between 3 to 5 years	10
	f. More than 5 years	10
4	**Number of Semesters teaching the current engineering courses**	
	a. 1 semester	3
	b. 2 semesters	6
	c. 3 semesters	10
	d. More than 3 semesters	81
5	**Number of Training related to Complex Engineering Problems (CPS) and Complex Engineering Activities (CEA) within the academic programmes**	
	a. None	10
	b. 1 time	16
	c. 2 times	19
	d. 3 times	16
	e. More than 3 times	39
6	**Number of EAC Training Attended**	
	a. None	10
	b. 1 time	13
	c. 2 times	23
	d. 3 times	13
	e. 4 times	6
	f. More than 4 times	35
7	**Number of Training related to Teaching, Learning & Assessment**	
	a. None	6
	b. 1 time	10
	c. 2 times	26
	d. 3 times	0
	e. More than 3 times	58

As shown in Table I, most of the respondents (87%) hold a PhD, indicating a high level of expertise and specialization in the field of engineering. In terms of years of experience as academicians, the 2 largest groups consist of individuals with 10 to 15 years of experience (29%) and those with 15 to 20 years of experience (29%). Another 19% respondents have experience more than 20 years, and 16% has 5 to 10 years of experience. This indicates a significant presence of highly qualified and experienced academicians in the survey.

CEP and CEA are often associated with the solution of real-life industrial problems. The data reveals adequate industry experiences amongst the respondent to conduct CEP and CEA teaching and learning. The largest 2 groups have 1 to 2 years (22%) and 2 to 3 years of industrial experience (22%), respectively. Another 20% has more than 3 years of experience and only 26% has experience less than 1 year in the industry. Note that this does not include academia who maintained active industry involvement alongside their academic roles. The data indicates a strong representation of respondents who have taught the current engineering courses for more than 3 semesters (81%). This highlights the presence of experienced instructors who have significant familiarity with the engineering curriculum and the subject matter.

In terms of training related to Complex Engineering Problems (CEP) and Complex Engineering Activities (CEA), only 10% have not attended any related training. There are 16% who have attended one training, whereas the remaining 74% have attended twice or more training sessions to be equipped and stay updated with CEP and CEA best practices. The high percentage indicated strong commitment to professional development amongst the respondents and is also indicative of the importance placed on acquiring the necessary skills and knowledge for effective teaching and learning in the respective programme and institution.

For the attendance of related training by the Engineering Accreditation Council (EAC) but not specifically related to CEP and CEA, the percentage is similar. There are 10% who have not attended any training, 13% have attended once and 77% have attended twice or more, suggesting a widespread recognition of the importance of aligning educational practices with accreditation standards.Meanwhile, only 6% has not attended any training related to teaching, learning, and assessment. The majority of respondents (74%) have attended twice or more related training for professional development to enhance their pedagogical skills and staying updated with effective teaching practices.

Overall, the analysis of the demographic profiles indicates a group of highly qualified and experienced academicians with adequate industrial exposure, who actively stay in tandem with the advances of the education sector through continuous professional development. They are thus most competent to plan, design and conduct teaching and learning activities for CEP and CEA in engineering programmes.

B. Courses Assessing CEP and CEA in Curriculum

Fig.1 presents the courses designed to assess CEP and CEA in the engineering curriculum based on the respondents' feedback.

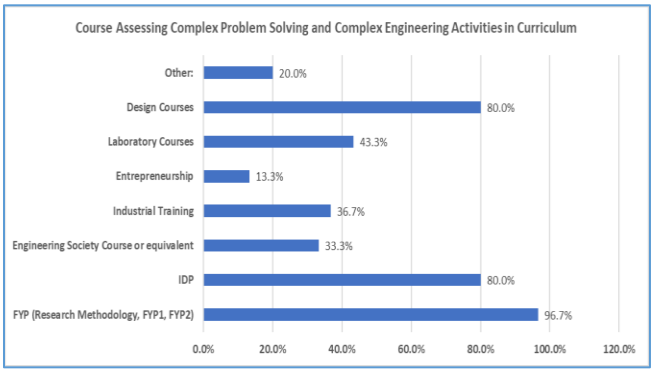

Fig. 1. Courses Assessing CPS and CEA in Curriculum

The result shows that the Final Year Project (FYP) is most commonly used by engineering programmes to address CEP and CEA (96.7%). This underscores the significance placed by programme owners on the FYP course for students to apply their knowledge and skills acquired throughout their engineering education to a research-based project, enabling them to demonstrate their abilities in undertaking complex engineering problems solving and complex engineering activities. The Integrated Design Project (IDP) and design courses are also popularly used by engineering programmes to address CEP and CEA based on the respondents' feedback (80%). This reveals the importance of design-oriented approaches in evaluating students' proficiency in CEP and CEA. The findings is similar to the previous study [9], where complex engineering activities were found to be addressed in Final Year Project, Industrial Training and Integrated Design Project and laboratory courses. In the present study, 43.3% respondents indicated the use of laboratory courses to address CEP and CEA.

C. Frequency of CEP and CEA Assessment in Curriculum

Fig. 2 shows the frequency of CEP and CEA assessment in engineering programmes. The implementation of CPS and CEA assessment are predominantly conducted every semester (80%). The planned assessment every semester indicates the significance placed on regular evaluation and monitoring of students' progress in the development of CEP and CEA skill in related subjects throughout the academic study. The curriculum thus allows students to continuous be exposed to CEP and CEA to hone the skill under different subjects and the guidance of different lecturers. It also provides opportunity for timely intervention should the student perform poorly.

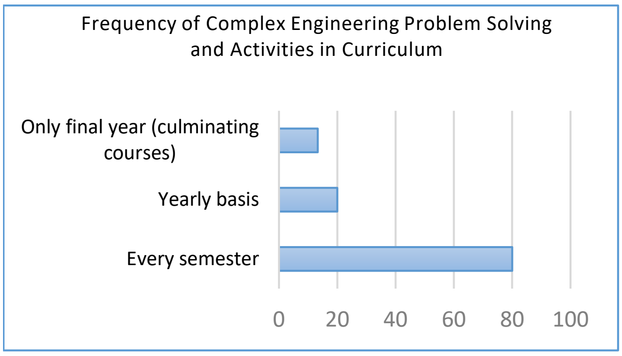

Fig. 2. Frequency of CEP and CEA Assessment in Curriculum

There are 20% responses which indicated assessment of CEP and CEA only in the engineering final year. This approach focuses on comprehensive evaluation of the skill prior to student graduation only. Students should have acquired CEP and CEA concepts and skill throughout their engineering programme and are expected to demonstrate their attainment in the related assessment in the final year courses and the culminating courses.

A smaller percentage of respondents (13.3%) indicated yearly assessments of CEP and CEA. In this approach, the assessment is spread out over the academic years but not necessarily in consecutive semesters. While less common, the phased assessments provide opportunity for interim review and intervention to facilitate the progressive development of the skill amongst the students.

D. Teaching and Learning Strategies to foster CEP and CEA in Courses

Fig. 3 indicates problem-based learning (PBL) as the most widely used teaching and learning strategy for CEP and CEA, with 76.7% of respondents suggesting its implementation. PBL is an instructional approach that engages students in solving real-world problems, encouraging active participation, critical thinking, and the application of knowledge. This strategy aligns well with the nature of CEP and CEA, as it promotes hands-on learning and problem-solving skills development. Academicians need to teach thinking and augment problem-based learning due to the students' different levels of motivation, different attitudes about teaching and learning and different responses to specific classroom environments and instructional practices [17].

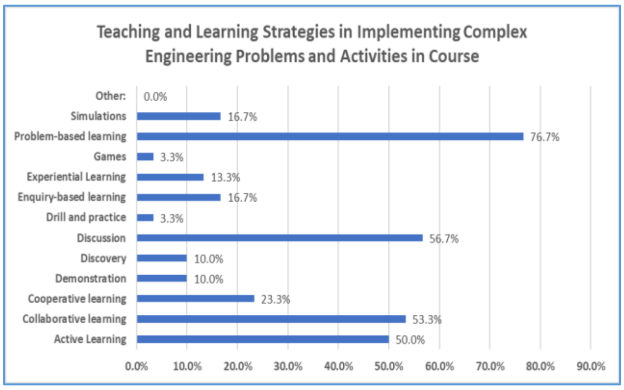

Fig. 3. Teaching and Learning Strategies in Implementing Complex Engineering Problems and Activites in Courses

Discussion-based approaches are also popular, with 56.7% of the respondents emphasizing the importance of discussions in teaching CPS and CEA. Discussions provide a platform for students to exchange ideas, share perspectives, and deepen their understanding of complex concepts. By facilitating dialogue and encouraging active engagement, discussions promote critical thinking, collaboration, and the exploration of different solutions and perspectives.

Collaborative learning (Coll-L) is used by 53.3% of the respondents as a teaching and learning strategy. This strategy allows students to work together in groups or teams to solve problems, complete projects, or engage in activities. This approach fosters teamwork, communication skills, and the sharing of knowledge and expertise among students. Coll-L is particularly relevant to CEP and CEA, as these domains often require interdisciplinary collaboration and integration of different perspectives.

Active learning (AL) is adopted by 50% of the respondents as a strategy for teaching CEP and CEA. Active Learning involves engaging students in hands-on activities, experiments, simulations, or practical exercises. This approach promotes student participation, critical thinking, and the application of knowledge in real or simulated contexts. AL is well-suited for CEP and CEA, as it allows students to experience the practical aspects of these domains and enhances their problem-solving skills.

Cooperative learning (Coop-L) is employed by 23.3% of the respondents. It emphasizes working together in structured groups to achieve shared learning goals. This strategy promotes teamwork, communication, and the development of social skills. Although it is less common, it can still be a useful approach in fostering collaboration and knowledge sharing in the context of CEP and CEA.

E. Assessment Tools Used to Address CEP

Fig. 4 reveals a diverse range of assessment tools employed to address CEP in the engineering programmes. The findings show the prevalence of project-based assessments to address CEP (83.3%). A well-designed project work provides students with opportunities to tackle complex problems and engage in complex engineering activities, fostering development of their related problem-solving skills.

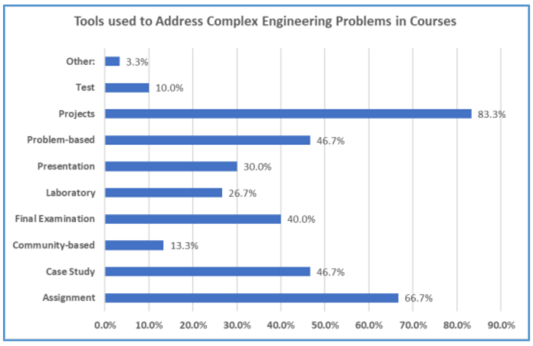

Fig. 4. Tools Used to Address CEP in Courses

CEP is also widely incorporated into assignments (66.7%). Assignments provide structured tasks that assess students' abilities to analyze and solve complex problems and engage in complex engineering activities, allowing them to demonstrate their attainment through written or practical work.

The other common tools are problem-based learning (PBL) and case studies which are employed by 46.7% of the respondents in their programmes, offering students real-world scenarios and complex engineering problems to analyze and solve. These assessment methods encourage critical thinking, decision-making, and the application of knowledge in authentic engineering contexts.

Previous study showed that most of the programmes in Malaysia addressed complex engineering problems in assignments or projects, but less so in final examinations and mid-term tests [9]. In the present study, the results show that 40% of the respondents uses the final examination as an assessment tool for CEP. This suggests the employ of examination question and answer scheme to provide comprehensive evaluation of students' attainment in complex problem solving.

Presentation-based CEP assessments are also used by 30% of the respondents. This tool requires students to effectively communicate their understanding and solutions to complex engineering problems using verbal and visual medium.

Other tools less commonly employed are laboratory, community-based learning, test, etc.

F. Assessment Tools Used to Address CEA

Unlike CPS which focuses on the cognitive domain, CEA is concerned with the affective domain.

Fig. 5 reveals that the most commonly used assessment tool for CEA is the final year project (73.3%) that provides students with an opportunity to apply their knowledge and skills to a comprehensive investigative project. This assessment tool allows students to manage a range of resources, innovate and demonstrate their life-long larning ability. In addition, communication forms an important part of the assessment, both in terms of technical reporting and technical presentation.

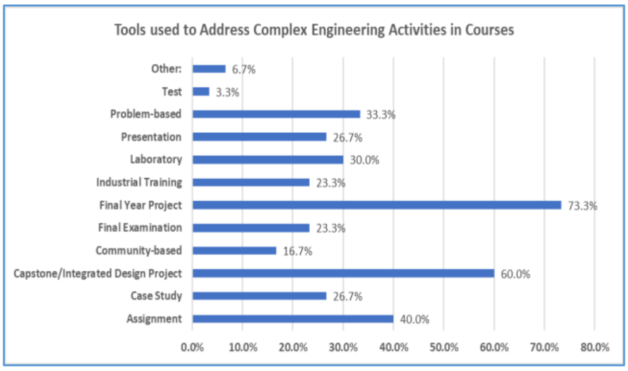

Fig. 5. Tools Used to Address CEA in Courses

Next widely utilised tool to address CEA is the Integrated Design Project (IDP) course (60%). IDP involves the integration of multiple civil engineering sub-disciplines to solve complex design problems. This assessment method also emphasizes the practical application of engineering knowledge in a collaborative setting.

Additionally, assignments, laboratories, and problem-based assessments are utilized by 40%, 30%, and 33.3% of respondents, respectively. meanwhile, case studies and presentations are used by 26.7% of respondents.

Note that many of the CEA assessment are done in group teaching and learning activities. These CEA assessment tools are characterised by interaction and communication, both within the group assigned, as well as with external parties (e.g. community, society). Previous study shows that students are receptive to carrying out tasks in small group, satisfaction with the evaluation through presentations and receive new knowledge [18]. CEA assessments also often contains the element of familiarity of issue, where students are given an acitivity setting not previously encountered to facilitate and stimulate the learning process.

V. CONCLUSIONS

This paper presents the prevalent practice in the implementation of complex problem solving (CEP) and complex engineering activities (CEA) amongst engineering programmes in Malaysia based on a pilot study. The test indicates that the survey instrument is reliable to be used in the main study. The findings include the courses selected to assess CEP and CEA, the basis of frequency in the assessment, the assessment tools used, and the teaching and learning strategies used to address the CEP and CEA in the courses throughout the engineering curriculum.

The culminating courses namely, Final Year Project, Integrated Design Projects, and related design courses having prominence of project-based learning are most commonly used to address CEP and CEA. Various assessment methods are reported to be used in line with the evolving high education landscape. The combination of project-based learning, assignments, problem-based learning, case studies, final exams, and presentations contributes to a comprehensive evaluation of students' competencies in critical engineering domains. Regular CEP and CEA assessment every semester is the most popular, which allows for continuous feedback and reflection to support students' ongoing growth.

Respondents' choice of CEP and CEA teaching and learning strategies reflect an emphasis on student engagement, active participation, collaboration, and practical problem- solving. These strategies aim to create a learner-centred environment that facilitates the acquisition of knowledge, skills and competency in the complex engineering domains.

VI. RECOMMENDATION AND FUTURE RESEARCH

Further research could focus on exploring the effectiveness and alignment of the assessment tools with desired learning outcomes in CEP and CEA. Additionally, investigating potential synergies and combinations of these methods can enhance the comprehensiveness and accuracy of evaluating students' proficiency in CEP and CEA. Further research can explore the effectiveness of different assessment frequencies on students' learning outcomes and their ability to apply CEP and CEA principles. Understanding the reasons behind the choice of assessment frequency can inform programme design and curriculum planning in CEP and CEA implementation. Further research could explore the effectiveness and impact of these teaching and learning strategies on students' learning outcomes, problem-solving abilities, and their ability to apply CEP and CEA principles in real-world scenarios. Additionally, understanding the challenges and facilitators in implementing these strategies in the context of engineering education can improve the pedagogical approaches and curriculum design for CEP and CEA.

ACKNOWLEDGMENT

We would like to express our gratitude to the Ministry of Higher Education, Malaysia for their financial support (FRGS/1/2019/SS03/UIAM/02/4), which has played a pivotal role in the successful execution of our research project. We would also like to extend our appreciation to the academicians who participated in the pilot survey.

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