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Guidelines for Developing, Supervising, Assessing and Evaluating Capstone Design Project of BSc in Electrical and Electronic Engineering Program

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Abstract**—**Inclusion of any design project in an undergraduate electrical and electronic engineering curriculum and producing creative ideas in the final year capstone design projects have received numerous comments at the Board of Accreditation for Engineering and Technical Education (BAETE) several times by the mentors and visiting program evaluator team members at different public and private universities in Bangladesh. To eradicate this deficiency which is needed for getting the program accreditation, a thorough change was required in the Department of Electrical and Electronic Engineering (EEE) for its BSc in EEE program at Southeast University, Dhaka, Bangladesh. We suggested making changes in the course curriculum titles and contents, emphasizing to include capstone design projects, question setting, examining students through other standard methods, selecting and retaining Outcome-Based Education (OBE)-oriented engineering faculty members, improving laboratories through purchasing new equipment and software as well as developing new experiments for each laboratory courses, and engaging the students to practical designs in various courses and final year projects. This paper reports on capstone design project course objectives, course outcomes, mapping with the program outcomes, cognitive domain of learning, assessment schemes, guidelines, suggestions and recommendations for supervision processes, assessment strategy, and rubric setting, etc. It is expected that this will substantially improve the capstone design projects offering, supervision, and assessment in the undergraduate EEE program to fulfill the arduous requirements of BAETE accreditation based on OBE.

Keywords**—**Course outcome, capstone design project, assessment and evaluation, electrical and electronic engineering.

I. Introduction

THE Capstone Design Project (CDP) course, also known as Capstone Unit or Senior Thesis or Senior Seminar or Final Year Design Project (FYDP), Senior Design Project (SDP), or simply Project means the culminating and cumulative knowledge of a program at tertiary level education. It is also referred to as a capstone experience, senior seminar in the USA, or final year project or dissertation in the UK. The term is derived from the final decorative coping or 'cap-stone' used to complete a building or a monument. In higher education, the term has been in use in the USA since the mid-twentieth century and as early as the late 1800s. Gradually it became popular in other parts of the world, particularly where graduate outcomes and employability after completion of the undergraduate studies were emphasized. National grant projects in Australia and the UK have raised the profile of the capstone experience [1].

The main objectives of CDP are to give the students in-depth knowledge and skills on project design and development, implementation and manufacturing, testing and validating, workflow management, dealing with financial as well as ethical issues, etc. while doing their design tasks. The entire students of a batch are given a real-life experience by forming the small groups who work under the supervision of a faculty member of the department to design, develop and implement a real-life project aiming to satisfy a certain number of a previously defined set of specifications. Finally, the students present their works through reports and presentations. During the project works, students get the opportunity to work with industry people as well as university faculty members simultaneously and gain experiences in any real-time engineering fields. In most cases, students can learn about new technologies and/or develop innovative ideas that are not in their academic curriculum. Hence this type of academic activity is beneficial to the students while they make a transition from student life to real-life upon graduation. Therefore, the CDPs provide a unique and compassionate environment for them as if they are working in an industry under the supervision of their faculty members as well as expert engineers working in the industry. Not only that, the industry can avail some benefits in solving their engineering problems through the suggestions and pieces of advice from the academicians and practical works of the students. This mutually beneficial partnership mechanism supports achieving academic excellence by ensuring the presence of a quality department with its vision, mission, and program educational objectives, and by building an environment where the students can have the practical experience of applying their classroom learning to actual industrial problems. This also assists the industry to discuss their problems with the students and faculty members of the university. On the other hand, this work supports the department in the sense that they can get financial benefits by sharing their knowledge and expertise, laboratory and its equipment, and gaining industry-level expertise. Besides, there remains an ample opportunity for the students of this course to be absorbed in the industrial jobs as they become familiar by this time with the industry people. Since engineering students are best served by early personal exposure to the excitement and challenges of the hands-on research and development areas, therefore, Capstone Research

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or Design Project transforms the engineering students into real-time professional engineers for the engineering job fields. The capstone project can create such type of opportunities for the students during their undergraduate study through the research, design, development, and implementation of the prototype works. An effective and fully operational implemented research and design project is the cornerstone of the undergraduate EEE education. In EEE program, the laboratory courses can be started at any level or term but the capstone project must be offered in the fourth level and should be spanned over one year as per the BAETE requirement [2]. There are many benefits of designing CDPs for final year students. A few of these are enlisted below:

1. For the undergraduate engineering students-
- Precious knowledge and skill enhancement in the proper EEE areas
- An amalgamation of the theory and laboratory courses' knowledge and skills with the practical and applied fields of EEE
- Students' CV becoming worthy and demanding to the potential employers
2. For the supervisors-
- Having vast experience in mentoring and dealing with students, colleagues, and other apposite officials
- Speeding up of the on-going research works in hand
- Getting time-bound project works done in time
- Extending the existing projects
- Collecting funds for further research projects
- Implementing projects within a low budget
- Generating experimental and simulation data for the on-going research works or upcoming projects
3. For the graduate engineering students -
- Getting an enormous experience in mentoring and dealing with engineering students of the same field
- Speeding up of the own research works
- Having some teaching experiences
- Getting an opportunity to be involved in practical works and troubleshooting
4. For the Department-
- Intensifying the existing research projects
- Strengthening the undergraduate final year project
- Expanding the horizon of departmental research
- Applying to the financial sponsors for the on-going or upcoming research projects of the department

However, there are certain limiting factors, such as it requires more research laboratory space and more time for faculty, staff, and graduate students.

BAETE is a private professional board working independently under the Institution of Engineers, Bangladesh (IEB) responsible for peer review of various engineering programs in Bangladesh so that a set of minimum criteria are retained to augment the prevailing educational programs and to develop further programs. According to BAETE, the accredited programs provide the public, prospective students, student counselors, parents, educational institutions, professional societies, potential employers, governmental agencies, and professional boards of examiners, specific programs that meet the minimum criteria for accreditation [2]. BAETE criteria, set in 2017 and subsequently modified in 2019, assess the programs concerning the students, program educational objectives, program outcomes and assessment, professional component, faculty, physical facilities, institutional support, industry linkage programs, and financial resources [2]. As per BAETE standards, the professional constituent specifies the subject zones applicable to the relevant engineering but does not advocate any definite courses. It also says that the students must be well equipped for their specific engineering professional field through the undergraduate program curriculum that caps in a key design involvement centered on the knowledge and skills assimilated in prior theory and laboratory courses. It also suggests that the design practice should integrate national and international engineering codes and standards, UN sustainable development goals, and authentic restrictions, such as economic, environmental, financial, ethical, health and safety, social, political, sustainability, and manufacturability of the planned design outcome [2], [3].

The engineering graduates should be able to apply their knowledge of mathematics, science, and engineering fundamentals to analyze, formulate, interpret data, and design practical engineering systems, sub-systems, or components. The engineering program should prepare the students for lifelong learning and make them to work professionally and ethically in multi-disciplinary teams, to communicate in oral and written forms [4]-[6].

Engineering employers anticipate that the engineering graduates should be able to perform engineering jobs within a very short period or right after the appointment and hopes that the university should prepare their graduates accordingly. Consequently, the engineering programs need to engage the students in projects based activities for attaining such experiences that are similar to what the graduates will face in the industry [7]-[9].

The CDP is a culmination course where such sequential engineering activities are practiced right after the core and elective courses, experimental and simulation laboratories, mini project works in the course, etc. It is a fact that most of the program outcomes set by BAETE are possible to achieve through the CDP. Therefore, course outcomes setting and its assessment and measurement should be done in such a way so that through this assessment students' outcome attainments are properly demonstrated. This may also help improve the teaching-learning activities and methods of the department. In this paper, it is suggested how to improve the students' learning to achieve the course and subsequently program outcomes through the CDP in undergraduate EEE program based on OBE as per BAETE requirements. Besides, this paper reports on CDP course objectives, course outcomes, mapping with the program outcomes, cognitive domain of learning, assessment schemes, guidelines, suggestions and recommendations for supervision processes, assessment strategy, and rubrics setting, etc.

II. BSc in EEE Program of Southeast University

Southeast University has an undergraduate electrical and electronic engineering (BSc in EEE) program. The faculty members have very limited specializations with terminal degrees in EEE. There are five faculty members with Master's degrees in power systems and renewable energies, two faculty members who have the expertise and terminal degrees in semiconductor devices, and four faculty members who have terminal degrees in physics, mathematics, and chemistry. But this is not adequate to develop the students with specialties in EEE CDPs. It is required that the students enroll in core courses. The courses have analysis and design components and it is up to the course teachers whether or not to assign course level design projects. Besides, there are elective courses that are offered by rotation as per the needs of the students. The elective courses in the curriculum are divided into four major areas of specializations, viz. power, bio-energy, renewable energy, electronics, communications, and computer [10].

In the BSc in EEE program of SEU, the power and energy group includes power system, power system protection, high voltage engineering, power electronics, and associated laboratory courses. Besides, this group has non-laboratory courses like green power and energy, power system economics, power system reliability, power plant engineering, nuclear power engineering, power system operation and control, electrical energy conversion machines and power systems analysis, etc.

The electronics group includes VLSI II, optoelectronics, hardware design with VHDL, nano-electronic devices, etc. Besides, this group has non-laboratory courses like green electronics, analog integrated circuits, compound semiconductor, and heterojunction device, semiconductor device theory, semiconductor processing, and fabrication technology, etc.

The communication group includes digital signal processing II, optical fiber communications, digital communication, microwave engineering, and associated laboratory courses. Besides, this group has non-laboratory courses like green communication engineering, mobile cellular communication, telecommunication engineering, satellite communication, optical networks, random signals and processes, radio and television engineering, broadcast engineering, radar, and navigation, etc.

The computer group includes courses on microprocessor-based system design and computer networks and associated laboratories. Besides, this group also has few non-laboratory courses like real-time computer systems, multimedia communications, computer architecture, green computing, cryptography, and network security, etc.

In the Department of EEE, there are no faculty members who are specialized in communication and computer engineering. Communication and computer engineering related core and elective courses are taught by non-specialized faculty members having master degrees only. The elective courses are offered during the fourth year of their undergraduate study. Students must do their major in one group and minor in one group only from any four groups. To fulfill or to meet the minimum credit requirements for the degree of Bachelor of Science in EEE, a student must take at least any four 3-credit theory courses of which two courses must include 1-credit laboratory if this group is a major group and any two 3-credit theory courses of which at least one course must include 1-credit laboratory if this group is a minor-group. If he/she wants to take more laboratory-based courses then his/her total credit requirements for the degree will increase according to the number of extra credits taken. But a student cannot do major in more than one-course group [10].

III. CDP of BSc in EEE Program

The students and the faculty supervisors should keep in mind that the criteria that BAETE has pressed in the final year CDP are engineering standard codes, teamwork, ethical engineering issues, respect to safety, societal impact, environmental and sustainability, project management, and finance, etc. The CDP should provide solutions to social problems, have the impact of the project in the local and global economy, and have the application of previous knowledge of the course curriculum.

Perhaps the most challenging task is to search for a project which has real-life applications with multiple levels of difficulty and requires three equal semesters in a year to accomplish. It has been proposed that the local industry in consultation with the university should send a few industry-grade unresolved problems and the program of the university should form an industry advisory panel through which these problems will be given to the students for solving. Thus a pool of practical and real-life projects can be obtained by forming a design clinic. The students may also propose projects having merit and practical interest. But this must be approved by the concerned supervisor and should be included in the design clinic. Next, the projects among the students will be distributed based on criteria set before [4].

A. Components of CDP

CDP has the following two most essential components: Lecture and Laboratory. The lecture component provides the students with specific knowledge and skills in designing and implementing the project, managing the time and monetary constraints whereas the laboratory component permits the students to design, implement, and verify the design project through tests and measurements.

To incorporate the CDP in the curriculum of the undergraduate level EEE program, a major modification in the curriculum as well as to the system is required especially the assessment and evaluation of the students in the capstone design course. To implement a completely new and innovative, proper training for the faculty members is required. Students must be made aware of it properly and trained on how to implement the project from scratch. Project implementation must reflect the applications of knowledge gathered from both core and elective courses in real-time design problems. Faculty and industry supervisors from both university and partner industries must conduct the lecture and laboratory classes. The cutting-edge engineering and technical software and modern tools must be purchased to do the simulation and verification work by the research students to embrace them with the new design tools and techniques so that they can grasp the concepts of real-time design works and become familiarized with such type of environment. In the second and third years, students must be given course level design problems that reflect efficacious real-world projects required for the industry. The curriculum breadth and depth of the undergraduate EEE program must reflect the latest engineering discoveries, innovations, and practices of the real-life cases. Any type of engineering design necessitates innovation for open-ended complex and multi-disciplinary problems. The latest versions of the high-tech software, viz. MATLAB, PSPICE, Cadence, Verilog, and VHDL must be made accessible in the research and working laboratories and the engineering students must be exhilarated to utilize that software to implement their design projects works in the laboratories of the EEE department [3], [11]. This process requires a cluster of dedicated, dynamic, and qualified faculty members together with passionate and painstaking as well as committed students. However, to have such kind of effective manpower, the university must have an attractive salary package, incentive, and performance bonus system, reward policy, strategy to retain them in the department. Though, none of these factors were addressed in the EEE Department at Southeast University (SEU); therefore, this is now high time to address these issues and take steps in the right direction to make a rigorous analysis of it and bring the necessary changes.

B. CDP Course Details

CDP should be offered over one year as a BAETE requirement in its manual since BSc in EEE program of SEU is being offered in 3 semesters in 1 year. As a result, the CDP course should be offered in three consecutive semesters in the final year of the program. As such, CDP has been split into 3 codes and titles, such as EEE492 CDP I, EEE494 CDP II, and EEE496 CDP III with 2 credits in each semester. However, if a student is in 4th year but he/she has not completed at least 120 credits then he or she cannot register in this course. To advance to the next CDP course, a student has to pass the previous CDP course first [10].

Course contents of the ‘Capstone Design Project’ of the EEE Department involve a group of students who design, build, and test a system, component, or engineering process. CDPs are selected from the problems submitted by the faculty members and local industries while industry projects are given preferences as they are well-matched to fulfill the course objectives and outcomes. The instructional phase includes (but not limited to) proposal preparation and reports writing methods, working methods, communication techniques with the group members, use of visual aids, design and development steps, etc. The performance phase includes (but not limited to) team formation and organization, design proposal submission, implementation of the design process, project scheduling, management and finance, design reviews, design simulation, and testing, preparation of documentation and presentation, drawings, and specifications, written report submission following the formatted template of the department, midterm oral presentation of partially completed projects and final poster presentation of the fully completed projects.

C. CDP Course Objectives

The objectives of this CDP course are to teach the students how to [10]-

1. Identify engineering problems, build an appropriate strategy to solve the problem systematically with given constraints of resources, budget, time, etc.
2. Analyze, design, build, and test engineering system/ subsystem within the given specifications, constraints and requirements, and engineering standards
3. Identify the impact of economic, environmental, social, political, ethical, health and safety considerations and constraints in the project and also validate it
4. Identify and assess the impact of usability, profitability, fabricability, and viability of a CDP
5. Apply the acquired knowledge and skills of the theory and laboratory courses completed in several semesters during the undergraduate engineering study
6. Use modern design tools in the design process and validation of a system/subsystem
7. Work in a multi-disciplinary team environment in the engineering profession
8. Demonstrate the development phases of EEE CDPs through the CDP proposal, time-line/Gantt chart of the project completion, requirement analysis, specifications list preparation, project design, final report, etc.
9. Exhibit the work through presentations using PowerPoint (midterm and online mode) or poster (on-campus)
10. Recognize the importance of life-long learning in the engineering profession
11. Demonstrate an understanding of ethical and professional responsibility in engineering project development phases.

D. Program Outcomes of BSc in EEE Program

The Bachelor of Science in EEE program offered at SEU requires that students earn the degree with minimum degree requirements of 153 credits following the guidelines set by the UGC, Bangladesh [12], and the BAETE, Bangladesh [2], [13]. The curricula have been designed by the academic committee comprising all the Faculty Members of the Department and the curriculum committee comprising two external academicians, one industry expert, one alumni representative, one college-level science teacher. Besides, we took the opinions of local and regional requirements from the Industry Advisory Panel (IAP) comprising 10 external industry expert members, 3 departmental faculty members, 2 external academicians, and 2 alumni. There are twelve program outcomes of this program as suggested in the BAETE Manual [2], [13]. Graduates are expected to achieve the twelve attributes at the instant of their graduation from the EEE Department as mentioned in the manual provided by the BAETE [13] and adopted by the EEE

Department of SEU for its OBE-based curriculum of the BSc in EEE program [14].

TABLE I
COURSE OUTCOMES OF CDP AND ITS MAPPING WITH THE PROGRAM OUTCOMES OF BSC IN EEE PROGRAM

CO	CO Statement	Program Outcomes, Degree of Correlations: 3 = Strong, 2 = Moderate and 1 = Weak											
		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	Identify an EEE problem which is complex and propose a solution by systematically writing proper planning within some given constraints		3										
CO2	Analyze the problem, review the relevant kinds of literature and articles to have necessary technical information, propose a methodology for the works, and investigate the available resources for designing the complete system and its sub-systems				3								
CO3	Implement the designed system within the budgetary and time constraints using technical knowledge and skills, tools and techniques, or any modern tools			3									
CO4	Simulate the system using any modern tools and find the experimental results as well as analyze and compare the results acquired to meet the expected specifications					3							
CO5	Estimate the impact of EEE solutions in a global, economic, environmental and sustainability, health, safety, and societal context						3	3					
CO6	Identify the ethical issues that may arise during the design stages of the system								3				
CO7	Function in a team as a group member or team leader									3			
CO8	Communicate with all members to complete the project in time, and be able to write technical reports, present the works in oral and poster formats										3		
CO9	Recognize the importance of engaging in life-long learning												3
CO10	Manage and control financial issues of the CDPs											3	

TABLE II
COURSE OUTCOMES OF CDP AND ITS MAPPING WITH THE PROGRAM OUTCOMES OF BSC IN EEE PROGRAM AS WELL AS BLOOM'S TAXONOMY (BT) DOMAIN, DELIVERY METHODS, AND ASSESSMENT TOOLS

CO Statement	PO	BT Domain/ Level	Delivery Methods and Activities	Assessment Tools
[CO1] Identify an EEE problem which is complex and propose a solution by systematically writing proper planning within some given constraints	PO2	Cognitive/ Apply	Discussion on the project proposal, question and answer session	Project proposal form
[CO2] Analyze the problem, review the relevant kinds of literature and articles to have necessary technical information, propose a methodology for the works, and investigate the available resources for designing the complete system and its sub-systems	PO4	Cognitive/ Analyze	Discussion on Chapters 1 & 2, question and answer (QA) session	Chapters 1 & 2 of the report
[CO3] Implement the designed system within the budgetary and time constraints using technical knowledge and skills, tools and techniques, or any modern tools	PO3	Psychomotor/ Naturalization	Discussion on demonstrated project work QA session	Demonstrated project + Chapters 3 & 4 of the report
[CO4] Simulate the system using any modern tools and find the experimental results as well as analyze and compare the results acquired to meet the expected specifications	PO5	Psychomotor/ Naturalization	Discussion on Chapters 3 & 4, QA session	Chapters 3 & 4 of the report
[CO5] Estimate the impact of EEE solutions in a global, economic, environmental and sustainability, health, safety, and societal context	PO6, PO7	Affective/ Characterization	Discussion on Chapter 5, question and answer session	Chapter 5 of the report
[CO6] Identify the ethical issues that may arise during the design stages of the system	PO8	Affective/ Valuing		
[CO7] Function in a team as a group member or team leader	PO9	Affective/ Valuing	Weekly Meeting and Group Discussion	FGD
[CO8] Communicate with all members to complete the project in time, and be able to write technical reports, present the works in oral and poster formats	PO10	Affective/ Organization		FGD Final Report PowerPoint Slide, Poster
[CO9] Recognize the importance of engaging in life-long learning	PO12	Affective/ Naturalization		FGD
[CO10] Manage and control financial issues of the CDPs	PO11	Affective/ Naturalization	Discussion on Chapter 5, QA session	Chapter 5 of the report

E. Mappings of COs with POs, Taxonomy Domain, Delivery Methods, and Assessment Tools

There are three courses on the CDP, such as EEE492 CDP I, EEE494 CDP II, and EEE496 CDP III [10]. Mappings among COs and POs for each capstone design course of the program offered by the department of EEE at SEU are presented in the program outcome mapping matrix in Table I with the degree of correlations (3 is for highly correlated, 2 is for moderately correlated, and 1 is for weakly correlated). Besides, statements of the COs for the CDP course offered for the BSc in EEE program by the EEE department are shown in Table II including the relationship with POs, Bloom's Taxonomy domain and level, delivery methods as well as assessment tools. Levels of the cognitive domain are used for judging the knowledge [15] and 2 other domains of Bloom's Taxonomy are used for judging the skills and attitude levels.

F. Guidelines for the Supervision and Execution Processes of the CDP

Pre-requisite theory and laboratory courses using the state of the art software and hardware must be offered to the students and they must pass all such courses before undertaking the CDP. Thus the students will be equipped with the necessary technical and non-technical skills that will help them complete the CDP course successfully. The design course spans over three semesters (i.e. over one year as per BAETE guidelines/manual [2]) from the commencement to the full-functional designed and implemented product. The students must look for an industrial sponsor, or a financial partner, or an entrepreneur to provide the project expenses with the cooperation of their supervisors.

Every group must provide a project proposal with objectives, methodology, financial and design constraints, design specifications, timing schedule, and possible outcomes of the product to be implemented. It is suggested that the design must be simulated and tested over and over again using any standard software before going for final implementation, viz., PSPICE, Cadence, MATLAB [16], VHDL, Verilog [17], SILVACO, etc. until the satisfactory outcome is achieved.

The CDP is offered at the beginning of the fourth year of undergraduate study. Students may take the 'Capstone Design Project' after completion of at least 120 credits of their course work as partial fulfillment of the requirements of their degree of BSc in EEE. Usually, the students enroll in both the design project and the elective courses in the fourth year. The knowledge and depth of the core and elective courses usually help the students complete the design projects successfully.

The students must complete this work within three consecutive semesters in the final year or at the fourth level of their academic degree program under the supervision of a Faculty Member of the EEE Department of SEU. The first, second, and third parts should be completed at Level IV, Terms I; II, and III respectively. The work has to be completed either separately or in a group comprising only 2- 3 students. Upon successful finishing of the assigned task, the students have to submit a CDP report on their findings and must present their works by appearing at an oral presentation in the middle of the semester. At the end of the third semester, there will be an oral test and also a poster and project showcase, which will be judged by the 4-member Board of Examiners formed by the Chairperson of the EEE Department. The Chairperson may also invite an External Member outside the Department or from any other academic institution or industry-relevant to the EEE field [10]. The CDP should be the design and implementation of a practical and/or real-life system or sub-system or solving a real-life problem in the fields of EEE or in any multi-disciplinary areas of engineering.

A Faculty Advisor will be assigned to each CDP for supervision and guidance throughout its entire period. Besides, there may be one or two mentors for each group or several groups of students. The student's teams in the second or third course of the CDP course, i.e. CDP II or CDP III respectively may perform as mentors and consultants to the student's teams in the first course, i.e. CDP I. Thus more open discussion among the students is possible and hence collaboration and teamwork skills of the students will improve. The students can go to faculty members of the department for consultancy in addition to the professional BSc engineers working in the industry as collaborators. Sometimes such informal discussion among the students and the faculty members can provide insight and novel ideas that may advance help to finish design projects more quickly. The Coordinator of the program coordinates the CDP assignment and supervision with the assistance of the faculty members of the Department [10].

CDP must be in the field of EEE if a student is in EEE Program and the Program Coordinator collects the list of projects from the faculty members and industry and publishes it in the departmental notice boards. Students may choose a project from the published list. Each CDP is performed by a group of three students. Though the work will be continuous for these three courses, the grading will be done individually after every semester.

During the first semester of the final year, the students are given general ideas on how to explore and choose a CDP. Groups are formed by the students, submitted to the Program Coordinator, and approved by the Department Chair. Students submit their draft proposal to the Program Coordinator. Each team has a leader. The Faculty Advisor must meet the teams every week to get an update of the project progress and advise necessary suggestions. The team leader divides the project into small modules and assigns each member a few modules to finish within strict deadlines. Every task done by the team members must be documented properly including successes and failures. In the second semester of the final year, the student should be able to accumulate their project modules in full and then test and verify. In the final semester, they must prepare the project report, poster presentation, and address the corrections and modifications suggested by the board of examiners. Students may participate in the national design competitions for innovative and creative designs in the fields of EEE.

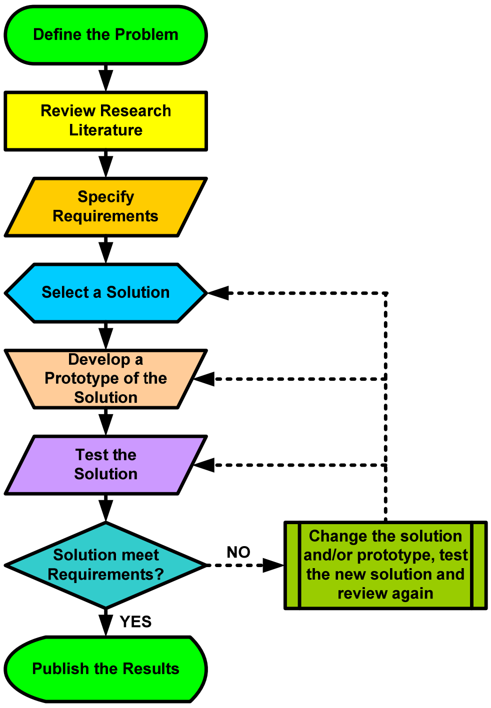

Fig. 1 Design cycles of the CDP

An individual project often has a "standard model" of normal research with a design cycle that contains various components. Any kind of engineering design process involves a series of multiple steps that everyone should follow to solve the problem. On many occasions, the solution involves designing a system or a part of it (for example, a machine or its component design, product manufacturing, or computer program development) that meets certain criteria and standards to accomplish one or several types of tasks. If the project involves designing, implementing, testing, and verifying something meeting some specifications or requirements, that is, more engineering-oriented projects then it might have an engineering design process cycle given in Fig. 1. Students may follow such a design cycle for their works. Obtaining financial support is necessary for engineering-oriented project design works but it is not mandatory right now for the students of the EEE Department at SEU.

The following points should also be kept in mind for CDP supervision and execution-

i. BAETE (Criteria 6, sub-criteria 3 in its second version of the manual) requires that each student must have a Final Year/Capstone Design Project (FYDP/CDP) experience in the final year. This requirement must extend for one year.

ii. CDP represents a culminating demonstration of the program outcomes at the level of solving complex engineering problems based on the knowledge and skills acquired in earlier course works incorporating appropriate engineering standards/codes and multiple realistic constraints. CDP should also address at least one of the 17 Sustainable Development Goals (SDGs) set by the United Nations through complex engineering problem-solving.

iii. The execution of each CDP is managed by the Project Coordinator selected by the Department Academic Committee. This committee should execute the whole process of CDP supervision, recording, monitoring, and evaluating.

iv. They have to abide by the following few guidelines of selecting the CDP topic while taking topics from the prospective supervisors of the department:

a. The topic should reflect the passion and interest of the group of students.

b. The topic should be realistic, has practical value and applications.

c. The project idea may come from the experience, thoughts, and learning of the students.

d. Students are highly encouraged to survey and analyze societal and industrial needs.

e. Faculty members should be given some sample topics.

f. Students may propose their topic and approach any faculty member to be their supervisor or mentor.

g. The topic and the supervisor or mentor must be fixed by the end of the previous semester (in this case, maybe the last week of the semester).

v. The progress of the project is monitored by the supervisor in the department each week. Students must submit their weekly progress reports to him/her for the assessment of the progress and volume of works done.

vi. Design projects must be submitted to the department coordinator when it fully functional.

vii. An oral/poster presentation of the design project is arranged after the completion of the project. A four-member board of examiners will examine the projects.

viii. A final soft and hardcopy of the project report that conforms to the standards set by the Department of EEE are also required.

ix. Students must showcase their design projects at the Annual CDP Open House Exhibition. This is a mandatory requirement.

x. Without successful completion of the CDP and going through all the processes in the final year of their undergraduate studies, a student cannot get the graduation certificate.

IV. Assessment Criteria and Feedback

While assessing the CDP, it should be kept in mind whether there are innovation and creativity in the completed project or not. Simple design and implementation are not acceptable. Besides, the complex design is also not accepted if it is already done by somebody beforehand. But the repetition of work may be accepted if there is any new modifications are made to improve the performance or to increase the lifetime or to reduce the implementation cost. However, the students should be made aware in advance of these criteria of assessment or acceptance of the CDP. At the end of every semester, the students should present their work either in PowerPoint or poster. The presentation will be judged by a board of examiners formed by the department chair. In the presentation, the students must demonstrate their CDP and report with pertinent test data in tables, graphs, figures, etc. Any kind of technical and non-technical problems and challenges that have been encountered, addressed, and solved must be discussed during the presentation and written in the report that is submitted to the department. This will assist the upcoming groups who will be taking CDP next time.

A. Assessment of the Progress of the Work

Fig. 2 shows how the CDP may be completed over one year period. The diagram shows how the progress of the work will be going on sequentially.

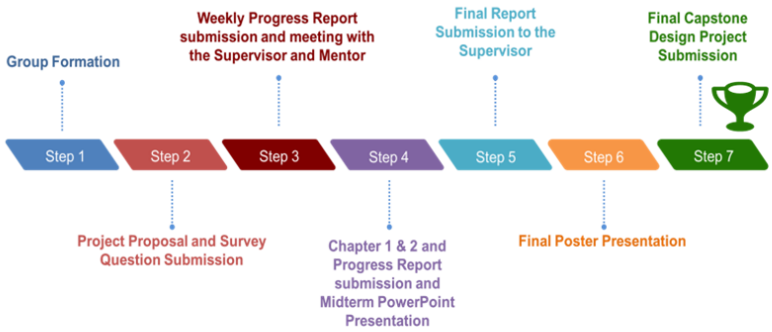

Fig. 2 Progress of work flow chart of the CDP

If the CDP can be implemented precisely following all the steps described in Fig. 2 and then using the outcome of the work, viz. designed circuit or system diagram, experimental or simulation data, analysis, and discussions, etc. may be published in a journal or presented in a conference. Students are graded by their supervisor and a Board of Examiners formed by the EEE Department Chair for the entire project extending over 1 year. However, since there are three semesters in a year at the EEE department of SEU therefore, project evaluation is done at least three times in one academic year whenever a group completes their project work.

To prove that their work has been completed, they have to publish it as an article in a peer-reviewed journal or present it in a conference and subsequently publish it in the proceedings of that conference. However, they have to appear in oral presentations several times in their three registered academic semesters of their final year, and a final poster presentation in the final semester before the Board of Examiners. During the progress of the project works, several guest lectures may be provided to the CDP students on the following topics but are not limited to:

a. Intellectual Property
b. Science, Engineering and the Law
c. Technology Transfer
d. The Nature of Small Businesses
e. Global Issues
f. Ethics
g. Difference between CDP and Thesis

B. Requirements and Processes of Assessment

BAETE experts have recommended for student outcomes assessment standards based on abilities, activities, criteria, methods, feedback, and evaluations. It is expected that the instructors evaluate fairly his or her students based on the recommended standards [18], [19]. The supervisor can test the student's performance by checking the student's activities, such as progress report from the logbook, examining each hardware module developed, and the assembled prototype, simulated project module, etc. He can discuss with the mentor and team members individually to get information for evaluation. Besides, he should allow the students to demonstrate their technical and non-technical skills and abilities developed due to their project activities through their project presentation and discussion as well as responding to the questions posed to them [20].

The supervisor should be able to propose and apply a method by which he/she can measure the activities that the students will need to do. However, only an experienced faculty member can do it. Otherwise, the department will set some guidelines for the supervisors and mentors so that they can measure and evaluate the student's performance by giving them an appropriate letter grade at the end of the semester's final presentation. The supervisor should also provide feedback to each student of the team about their progress and should suggest how to improve their performance in implementing the project. If any deficiency is found in any step of conducting, guiding, supervising, assessing, or evaluating the CDP students that must be taken notice to the department chair or coordinator immediately to address the issue and suggestions can be made to exterminate such deficiency.

Comprehensive documentation starting from the project title, type, the literature reviewed, components used, cost and its break down, prototypes, project timeline, etc. should be recorded and provided to the supervisor or adviser of the project on a weekly or bi-weekly basis as decided by the department. The supervisor should assess and document the progress of each member of the group individually under his/ her [18], [19]. Thus the supervisor will be able to evaluate and grade each member of the group at the end of the semester in a fair manner.

After the end of the project presentation, a survey must be conducted upon each member of the group anonymously before the students leave the department. After that, a follow-up survey must be conducted three to five years after graduation upon the same group members.

C. CO Assessment Methodology

Detailed guidelines for assessment criteria and tools to evaluate student performance on CDP are given in Table III.

TABLE III
ASSESSMENT CRITERIA AND TOOLS TO EVALUATE STUDENT PERFORMANCE

CO Statement	PO	Assessment Criteria	Assessment Tools	Time Frame
[CO1] Identify an EEE which is complex and propose a solution by systematically writing proper planning within some given constraints	PO2	Validate problem statement, identification and planning the solution through the project proposal and presentation	CDP_RUB_1 for CDP Proposal CDP_RUB_2 for Project Proposal Presentation	First Semester Midterm Presentation
[CO2] Analyze the problem, review the relevant kinds of literature and articles to have necessary technical information, propose a methodology for the works, and investigate the available resources for designing the complete system and its sub-systems	PO4	Literature Review Proposed Methodology	CDP_RUB_3 for Methodology from Chapter 1 CDP_RUB_4 for Literature Review from Chapter 2	First Semester Final Presentation
[CO3] Implement the designed system within the budgetary and time constraints using technical knowledge and skills, tools and techniques, or any modern tools	PO3	Demonstrate the implemented system Report writing on budget and time constraints	CDP_RUB_5 for Chapter 1, Section on management, financial, and time frame. CDP_RUB_6 for Chapter 4 on model development	Third Semester Midterm Presentation
[CO4] Simulate the system using any modern tools and find the experimental results as well as analyze and compare the results acquired to meet the expected specifications	PO5	Demonstrate the effectiveness of modern tool use	CDP_RUB_7 for Chapter 3 on modern tool use	Second Semester Midterm Presentation
[CO5] Estimate the impact of EEE solutions in a global, economic, environmental and sustainability, health, safety, and societal context	PO6, PO7	Evaluation of economic, environmental and sustainability, health and safety issues in societal contexts	CDP_RUB_8 for Chapter 1 and 6 on those issues	Third Semester Poster Presentation
[CO6] Identify the ethical issues that may arise during the design stages of the system	PO8	Assessment on plagiarism and other ethical issues	CDP_RUB_9 for a section in Chapter 1 and 6 on it	Third Semester Report
[CO7] Function in a team as a group member or team leader	PO9	Assessment of teamwork ability through viva-voce and meeting documents	CDP_RUB_10 for Project Group Viva-Voce	Second and Third Semester Viva-Voce
[CO8] Communicate with all members to complete the project in time, and be able to write technical reports, present the works in oral and poster formats	PO10	Assessment of communication and project management	CDP_RUB_11 for Project Proposal CDP_RUB_12 for Poster of CDP	Each of 3 Semesters' Final Poster Presentation
[CO9] Recognize the importance of engaging in life-long learning	PO12	Assessment of Future Scopes of the project	CDP_RUB_13 for a section in Chapter 6	Final Report
[CO10] Manage and control financial issues of the CDPs	PO11	Assessment of Final Report on CDP	CDP_RUB_14 for the Final Report	Final Report

To assess the students of the CDP course, the policy is adopted as shown in Table IV.

TABLE IV
ASSESSMENT THROUGH ACTIVITIES OF CDP

Activities	Assessment Method	Assessor	Weightage
Project proposal submission	Project proposal form	Supervisor	10%
Weekly progress meeting	Log maintained by the students and the Supervisor	Supervisor + Mentor	15% (Average)
Midterm presentation	Oral presentation using PowerPoint + Report of Chapters 1 & 2	Supervisor + Internal Members	20% (Average)
Final poster presentation	Final Poster	Supervisor + Internal Members + External Member	30% (Average)
Final CDP Report	Rest of the Report from Chapter 3	Supervisor + Internal Members + External Member	25% (Average)

D. Preparing Weekly Log

A reflective document that provides a thoughtful analysis of individual participation/progress is called a log or journal. To articulate what students have learned and why the things they do, a student needs to maintain a weekly journal. In the end, they must submit a weekly journal to the supervisor. At the end of the semester, students should submit a full, accumulated collection of entries that reflect the thought process of their work throughout the semester. Besides, what they learn during their interaction with the supervisor and team members, what they contribute to the full project or a part of it, research/readings done to support the project independently, new technological skills they develop, and their plans for going about doing the work, what efforts they produce and why they succeed or fail- all these should be recorded in the journal. Students should be honest in their journal entries. A tentative working log is also provided as shown in Table V.

E. Report Writing Format of CDP

A tentative reporting outline has also been prepared and its template is provided to all students, supervisors, and mentors. The report outline is given as in Fig. 3.

TABLE V
WEEKLY WORKING LOG

Weeks	Activities
Week 1	• Distribution of course hand out and explaining the course to the student • Ask students to research on selecting one individual project topic and forming groups
Week 2	• Submission of group members name and topic (signed by the Mentor) • Oral presentation of the project topic, justify the topic
Week 3	• Discussion on research methodologies • Weekly progress by maintaining the journal
Week 4	• Discussion on communication skill • Weekly progress by maintaining the journal
Week 5	• Discussion on project management • Weekly progress by maintaining the journal
Week 6	• Discussion on engineering practice ethical issues • Weekly progress by maintaining the journal
Week 7 to Week 10	• Students describe their weekly progress to the class • Weekly progress by maintaining the journal
Week 11 to Week 12 (Supervisor and Mentor should be present)	• Students submit their interim report • Students present the project's current status through PowerPoint • Students demonstrate the operation of their project • Students submit the journals to the Course Teacher

F. Assessment and Evaluation

CDP is assessed and evaluated through a rubric. One of the rubrics is shown in Fig. 4. This is used to assess course outcome number one (CO1). There are 14 rubrics to evaluate the course outcomes of the CDP course.

Chapter 1: Introduction to the Project
- Motivation
- Problem Statement
- How ethical, societal, environmental, financial, etc. issues are addressed
- Objective

Chapter 2: Literature Review
- What are the current practices of the stated problem?
- What are the gaps found in the literature review?

Chapter 3: Methodology
- How the stated problem will be solved?
- Week- and trimester-wise planning

Chapter 4: Expected Results and Discussions
- Experimental and/or Simulations Results
- Discussion on Results correlating with the Standards and Codes those were supposed to be maintained
- Impacts of the Solutions

Chapter 5: Conclusions
- Concluding Remarks
- Future Scopes

References

Fig. 3 Final report outline of the CDP work

CDP_RUB_1: Rubric for Assessment of Capstone Design Project Proposal
Target Course and Program Outcome: CO1 and PO2

Southeast University

Serial #		Capstone Design Project Title	Semester:
Poster ID			

Project Member's Name and ID #	
	1.
	2.
	3.

Objectives	Very Poor (1)	Poor (2)	Average (3)	Very Good (4)	Excellent (5)	Marks (5) 1	2	3
Project Description	*It is unclear what is being proposed.*	*Only few aspects of the proposal are clear but most of them are unclear*	*The description is adequate but need further clarity and it does not explain project concisely with a clear picture*	*Description is clear, concise, and easy to understand but still few grey areas are there.*	*Description is fully clear, concise, and easy to understand.*			
Adequacy and Feasibility of Design	*Processes and procedures are omitted, impractical design.*	*Processes and procedures are vaguely stated, design is seemingly impractical.*	*Processes and procedures for executing the project appear manageable, but there is some uncertainty.*	*Processes and procedures are not well-stated but seem manageable.*	*Processes and procedures are well-stated, manageable and appropriate.*			
Components of the Proposal	*The report misses many important components*	*The report misses few important components*	*The report has important components but lacks many important description*	*The report has important components but lacks few important description*	*The report has all important components with proper description*			
Budget (Appropriateness and Justification)	*Budget is unreasonable in all areas. Costs are not justified in the budget narrative. Many costs are not relevant and essential to this project.*	*Budget is unreasonable in most of the areas. Costs are not justified in the budget narrative. Most costs are not relevant and essential.*	*Budget is comprehensive and reasonable but not explained clearly. Most costs are justified, relevant and essential to this project.*	*Budget is comprehensive, clearly explained, and appropriate for the activities proposal. Few costs are not justified/relevant/essential.*	*Budget is comprehensive, clearly explained, and appropriate for the activities proposal. All costs are justified/relevant/essential.*			
Objectives and Goals	*The objectives and goals of the project are not clearly stated or are nonexistent.*	*The objectives and goals are not clearly stated and most of them don't exist*	*The objectives and goals are not clearly stated but most of them exists*	*The objectives and goals are clearly stated but few of them don't exist*	*The objectives and goals of the project are clearly stated and all of them exist*			

Comments of the Supervisor:	Assessed by (Name, Sign & Date)	Total (Out of 25)	

Fig. 4 Rubric for assessment of CDP proposal

To assess the proposal, marks are given on a Likert scale of 1-5 as shown in Fig. 3. Then the supervisor puts marks for each objective of the rubric in the right-hand side column for each student of a research group comprising students' numbers not more than three. Then the total of all objectives is counted out of 25.

V. Conclusion

The prime object of any engineering educational program is to provide graduates with certain abilities to perform in real-life situations where they require performing in a multi-disciplinary team. The industry employers want the ready-made graduates from the industry, i.e., they want such graduates who will be performing in the industry right after getting the jobs after getting the certificate from the university. If their expectations need to be fulfilled then they must continuously provide feedback to the university about the engineering problems and challenges they are facing every day and the expertise and skills they are looking for in getting the solutions to their problems from the universities and their graduates. All assessment and evaluation results and feedback reports of the CDPs should be used to improve the course contents of the curriculum as well as assessment and evaluation strategies. This continuous quality improvement through evaluation and feedback will ensure the students' satisfaction in the department. However, they should be made aware of it properly. Various constraints like time, monetary, social, management, administrative, reliability, manufacturability, health and safety issues, environment and sustainability, ethical issues, engineering standards, and codes, etc. in the CDP are not usually a part of the engineering curriculum but these topics must be taught to the students in the CDP course.

The EEE program at SEU has undergone some changes concerning the final year design course to meet BAETE recommendations and guidelines/manuals. Some of the above ideas and suggestions have been made available to the faculty in the BSc in the EEE program at SEU. Surveys are being conducted among the existing students, faculty members, fresh graduates, alumni, employers, and parents, etc. This type of survey will surely help the supervisor and the department chair know about the CDP conduction and supervision processes and hence change any steps or processes that will ensure quality improvement in the future. It is important to hear from the practicing engineers who graduated from the department for future quality improvement of CDP supervision and guidance processes. Faculty members need to employ an extensive amount of time, energy, and effort in supervising the CDP for the undergraduate students of the EEE program. Therefore, they must be rewarded and compensated for their whole-hearted and extra-ordinary works and supervision.

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