Using InPods Platform for the Assessment of a Digital Design Course in the Baccalaureate Degree Engineering Technology Program

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***Abstract*—This innovative practice full paper describes the usage of a modern and powerful learning management system for the assessment of courses in the baccalaureate degree engineering technology programs. One such learning management system called InPods has been recently deployed at our university for the assessment of courses in the various baccalaureate degree engineering technology programs' curricula. A customized version of the InPods platform is being used at our university with an intention to implement Outcome-Based Education (OBE), which is a necessary step towards Washington Accord. In this paper, we will briefly describe our first-hand experience of using the InPods platform for the attainment of Course Outcomes (COs) and the correspondingly mapped Program Outcomes (POs) of a Digital Design course. The Digital Design course was offered during the spring semester of the Academic Year 2022-23 to over 1400 students majoring in various programs offered by the School of Computer Science and Engineering and the School of Engineering. One of the authors of this paper was the Instructor in Charge of the Digital Design course during its offering in the spring semester of the Academic Year 2022-23. To the best of the authors' knowledge, no work has been reported in the literature on the usage of the InPods learning management system for the attainment of COs and POs. All aspects starting from the content of the Digital Design course, the available laboratory facilities to support this course, pedagogical approaches adopted for teaching this course, assessment, and evaluation of this course using the InPods Platform will be briefly discussed. Presently, only the direct attainment of COs and POs is implemented using the InPods platform at our university. Therefore, only the direct attainment of COs and POs using the InPods platform will be briefly compared with that using the Faculty Course Assessment Report (FCAR) platform. Although both direct and indirect attainment of COs and POs for various courses using the FCAR tool has been reported in the literature. Finally, by using the preliminary results obtained from the InPods platform we will be able to analyze the offering of the Digital Design course at the freshman-level during the spring semester of the Academic Year 2022-23 at our university.**

Keywords*—Assessment, course outcomes, InPods, learning management system, outcome-based education.

I. INTRODUCTION

The Digital Design course has been assessed numerous times in the open literature. As ABET requires providing written skills for engineering students, the "writing-to-learn" theory was put to test by researching in a Digital Design Laboratory course, an undergraduate sophomore-level writing-intensive discipline-specific course in the School of Electrical and Computer Engineering at the Georgia Institute of Technology [1]. As ABET requires providing hands-on design experience for engineering professionals, efforts were made to create a set of laboratory exercises and projects of varying degrees of complexities suitable for an undergraduate Digital Design and Capstone course in the Department of Electrical Engineering at the University of the District of Columbia [2]. The persistence in engineering and the motivational tendencies survey instruments were administered both at the beginning and at the end of a freshman-level Digital Design course with an intention to evaluate the impact of this course in retaining students in the electrical and computer science/engineering programs offered at the Arizona State University Tempe campus [3]. A Digital Circuits course was used as an example to describe a method for obtaining relevant data needed for assessing ABET ETAC criteria in the School of Computing and Engineering Sciences at the Eastern Washington University [4]. Computer engineering students should be taught asynchronous circuit design in their curriculum to increase their preparedness so that they can take on the challenges faced by the digital design community [5]. The asynchronous educational modules presented in [5] have been used in several undergraduate and also graduate level courses at the Missouri University of Science & Technology and the University of Arkansas.

The inclusion of System-on-Chip (SoC) concepts in the Digital Design track of the Electrical and Computer Engineering curriculum at the Rowan University was discussed in [6]. The successful integration of programmable logic concepts in an introductory level Digital Electronics course offered for undergraduate engineering students at the Universidad Nacional del Centro de la Provincia de Buenos Aires was presented in [7]. A course on an integrated introduction to digital design and computer architecture that was taught for several years at Harvey Mudd College led the course instructors to publish the second edition of a textbook on "Digital Design and Computer Architecture" and also describing its content in [8]. The Digilent Design Contest sponsored by Digilant Inc. and Xilinx Inc. for freshman engineering students at Loras College was described in [9]. Through this contest, the freshman students enrolled in an Introduction to Engineering course at Loras College were able to create something with little or no knowledge of Arduino microcontroller kits [9].

The usage of Faculty Course Assessment Report (FCAR) methodology was described for the first time for the assessment of an associate degree course in an engineering technology program at Hafr Al-Batin Community College [10]. A course on Microcontroller Applications that had Digital Circuits II course as one of its prerequisites and a Cooperative Training course were taken as examples in describing an effective deployment of the FCAR tool in the historically ABET accredited Electrical and Electronics Engineering Technology (EEET) program at Hafr Al-Batin Community College [10]–[12]. Theme based projects were introduced in the Digital Electronics course offered at the sophomore-level in the Department of Instrumentation Technology at the BVB College of Engineering and Technology in order to make this course more interesting and increase the level of understanding among students [13]. A Digital Design Fundamentals course that was designed and implemented to be delivered in an online mode at the Arizona State University saw the conversion of an offline mode 15-week lecture-laboratory integrated Digital Design Fundamentals course to an online mode 7.5-week equivalent course [14]. Some of the drawbacks of the InPods Outcomes-Based Education (OBE) tool such as lack of customization of analytics and reports were identified in [15].

The direct assessment process of ABET student outcomes of the EEET program at Hafr Al-Batin Community College, which had Digital Electronics as one of its core course and the challenges faced during the Covid-19 pandemic were described in [16]. It was also noted that the ABET accreditation of academic programs is not taken into account by the university ranking agencies [17]. Curricula comparison among similarly named degree programs offered at the regional and international institutions is important and a couple of such case studies were reported in accordance with the General Criterion 5-Curriculum of the ETAC of ABET [18], [19]. The motivation, methodology, and results of incorporating active learning concepts in a Digital Design course for junior-level electrical and computer engineering technology students at Farmingdale State College, State University of New York were described in [20]. Finally, several Digital Design projects using Arduino and Raspberry Pi embedded boards were implemented by the freshman students of all engineering and technology programs at Presidency University [21].

In this paper, we will share our first-hand experiences of using a customized version of the InPods platform with an intention to implement OBE at our university. A Digital Design course is taken as an example in describing the usage of InPods tool. We will also make an attempt to provide a brief qualitative comparison between the InPods platform and the FCAR tool. Finally, by using the preliminary results obtained from the InPods platform we will briefly analyze the offering of the Digital Design course during the spring semester of the Academic Year 2022-23 at our university.

II. Assessment of a Digital Design course using the InPods platform

The Digital Design course coded as ECE2007 was offered during the spring semester of the Academic Year $2022-23$ to over 1400 students majoring in various baccalaureate degree engineering technology programs offered by the School of Computer Science and Engineering and the School of Engineering at our university. The ECE2007 course is usually offered by the Electronics and Communication Engineering (ECE) Department and taught by its respective faculty. One of the authors of this paper was the Instructor in Charge (IC) of the Digital Design course during its offering in the spring semester of the Academic Year $2022-23$. Digital Design is a 3-credit hour course at our university and has no prerequisites. It has two lecture sessions of fifty minutes each per week and one laboratory session of one hour forty minutes per week.

The Course Outcomes (COs) of the Digital Design course are shown in Table I. The expected Bloom's cognitive domain level in the CO1 is remembering or knowledge level, and the expected Bloom's cognitive domain level in the CO2–CO5 is applying or application level.

TABLE I: The COs of the Digital Design course.

CO#	Course Outcome
CO1	**Describe** the concepts of number systems, Boolean algebra, and logic gates.
CO2	**Apply** minimization techniques to simplify Boolean expressions.
CO3	**Demonstrate** the combinational circuits for a given logic.
CO4	**Demonstrate** the sequential and programmable logic circuits.
CO5	**Implement** various combinational and sequential logic circuits using gates.

The mapping of the Digital Design COs to Program Outcomes (POs) is shown in Table II. In this table, the acronyms L, M, and H mean Low, Medium, and High levels of mapping, respectively. As can be seen from this table, the Digital Design COs map to 7 POs of the ECE Department at our university. The POs of the ECE Department are formulated by referring to the five ABET Student Outcomes (SOs) as mentioned in the Criterion 3 of the $2023-24$ Criteria for Accrediting Engineering and Technology Programs. The PO1, PO2, PO3, PO4, PO5, PO10, and PO12 are related to engineering knowledge, problem analysis, design/development of solutions, conducting investigations of complex problems, modern tool usage, communication, and life-long learning, respectively.

TABLE II: The mapping of the Digital Design COs to POs.

CO#	PO1	PO2	PO3	PO4	PO5	PO10	PO12
CO1	H	M	L	L	L	L	L
CO2	M	H	H	L	M	L	L
CO3	H	M	H	M	M	L	L
CO4	M	M	H	M	H	M	L
CO5	M	H	L	H	H	M	L

Over 1400 students who were enrolled in the Digital Design course during the spring semester of the Academic Year $2022-23$ were grouped into 25 sections with roughly 60 students in each section. A total of 12 faculty members were handling the lecture sessions for roughly 2 sections each. For each laboratory session, the main instructor also had the support of one co-faculty and of course one laboratory technician. The laboratory experiments were either conducted on CircuitVerse - an Online Digital Logic Circuit Simulator or Multisim Live Online Circuit Simulator. There were 10 experiments ranging from verifying the truth tables of various logic gates, constructing and verifying 2-bit and 3-bit adder and subtractor logic circuits, constructing and verifying the multiplexer and demultiplexer logic circuits, constructing and verifying the encoder and decoder logic circuits, constructing and verifying the combinational logic circuit for given specifications, study of flip-flops, constructing and verifying the synchronous counter circuit, constructing and verifying the asynchronous counter circuit, to write the HDL code for a given combinational circuit, and to write the HDL code for a given sequential circuit. Each experiment had two levels. For example, In Experiment 1, the Level 1 was about the verification of the truth tables of various logic gates while the Level 2 was about constructing the basic logic gates using universal gates. Note that no midterm or end-term laboratory exams were conducted as per the present university policy. The laboratory component of the Digital Design course was assessed through laboratory report submissions. Some instructors also chose to conduct viva-voce examination along with the laboratory report submissions. The laboratory component of the Digital Design course weighed for 40 marks.

There were 3 modules to be taught during the lecture sessions. Module 1 of the course dealt with Boolean function simplification. Modules 2 and 3 dealt with combinational and sequential logic circuits, respectively. A portion of the Module 3 also dealt with programmable logic circuits. Ideally, faculty members are expected to deliver one and a half modules before the midterm examination and the remaining one and a half modules is required to be delivered before the end-term examination. Many faculty members have reported that two lecture sessions per week are not enough to teach the syllabus content which is spread across three modules. A proposal is underway to convert the course to 4-credit hours with 3 lecture sessions and 1 laboratory session. In the mean while, faculty members use a small portion of the laboratory sessions to cover the lecture topics. As the laboratory experiments are conducted using online simulators it is manageable to deliver some amount of theoretical content during the laboratory sessions without compromising on the laboratory content. But, delivering lecture content in a laboratory setup is a different kind of experience than a classroom kind of setting. It is challenging for a faculty member to have a good control over the students in a laboratory setup especially those students who are sitting in the last rows. Also, it is difficult to completely eliminate the problem of smartphone usage by some students during the laboratory sessions.

As there were 25 sections and 12 faculty members, some faculty members may be fast in covering the syllabus and some may be even slow depending on the pace of students' understanding in their respective sections. Therefore, some topics may be omitted from being delivered directly by the faculty member in the class such as HDL Models of combinational and sequential logic circuits, Mealy & Moore Models of finite state machines. These topics may be chosen either as a self-learning topic or a participative learning topic. In the case of a self-learning topic, students are expected to gather the information about the topic and should be aware about the significance of the topic. In the case of a participative learning topic, students are expected to form their own groups comprising of 5 to 6 students in each group and gather the information about the topic and should be aware about the significance of the topic. In both cases, students are expected to visit the central library at our university to collect the information. Moreover, the fast learners of the course are expected to share their understanding on these assigned topics in a classroom or a laboratory setting. Omitting any topic from being delivered because of shortage of time may happen based on the faculty feedback and the Instructor in Charge takes a final call on this through IC meetings. Keeping track of the syllabus coverage in all the 25 sections was important because midterm and end-term examination question paper sets were common for all students enrolled in the course.

Among the 25 sections, we have taken the data of two sample sections as an example that had about 60 students each. As can be seen from Figures 1 and 2, none of the course outcomes were attained by these two sections. Since the COs are not attained there is no point in analyzing the POs as they will not be attained too. Therefore, we have not included the PO analysis in this paper. Also, in Figures 1 and 2, targets and thresholds were set at 60% each, which means that we are targeting 60% of the total students from a given section to score the threshold marks of 60% of the total marks in order to attain a particular course outcome. The total marks for the Digital Design course are 200. These marks are distributed as follows: continuous assessments - 50 marks, midterm examination - 50 marks, and end-term examination - 100 marks. There are two components in the continuous assessments. They are laboratory reports, which constitute for 40 marks and an homework and/or a quiz, which constitutes for the remaining 10 marks. There are two passing criteria for the Digital Design course. First, a student has to score a minimum of 80 marks out of 200 marks. Second, a student has to score a minimum of 45 marks out of 150 marks (midterm and end-term examinations combined). In the second criteria, there is a chance that a student might have scored 45 marks in the midterm examination that was administered and the student may have been absent for the end-term examination, the student still satisfies the passing criteria. To determine whether students have passed or failed a course we don't need question-wise marks data collection, we only need to look at the two aforementioned criteria. The question-wise marks data collection is needed only for the CO-PO attainment analysis.

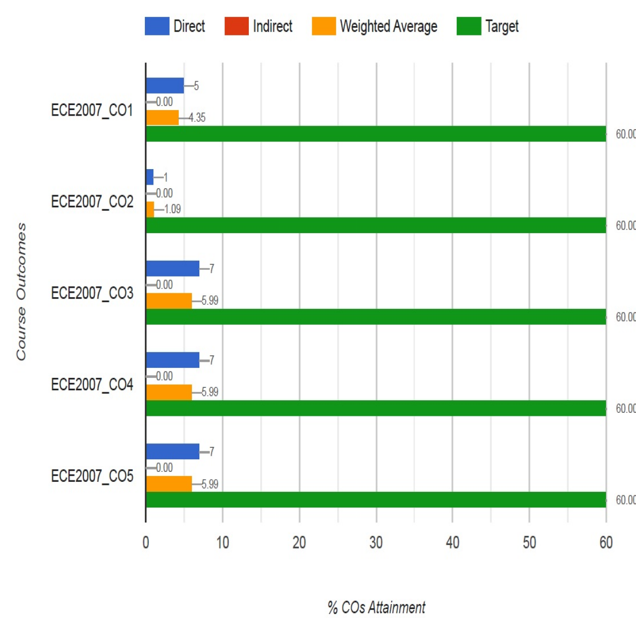

Fig. 1: Percentage COs attainment of the Digital Design course using InPods - Section 1.

As a pilot study only the data for two sections comprising of about 60 students each was captured in various Excel sheets for uploading on InPods for the required CO-PO attainment

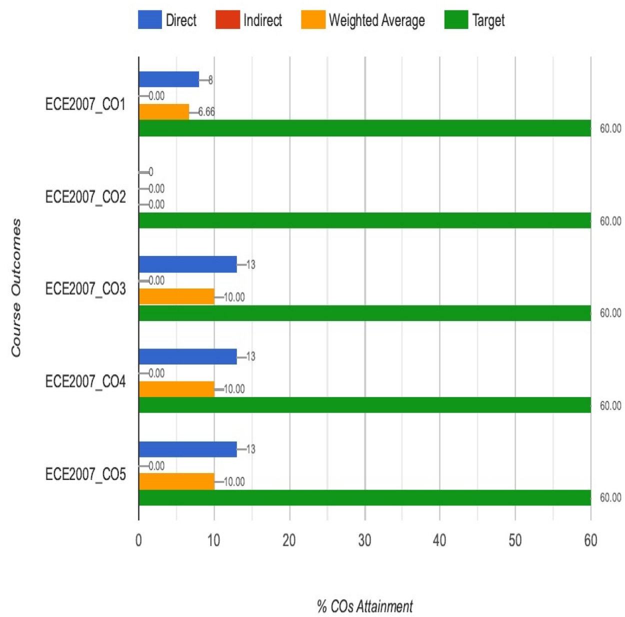

Fig. 2: Percentage COs attainment of the Digital Design course using InPods - Section 2.

analysis. To complete this task, the respective midterm/end-term examination evaluator of a particular section has to manually look at the midterm and end-term examination scripts of each student and record the question-wise marks in the respective Excel sheets. This is a laborious task. Given the volume of work, the precision with which students' question-wise marks data is captured may definitely be compromised, which may result in an erroneous CO-PO attainment analysis for a particular course. In that case, it is not possible to reap the benefits of implementing Outcomes-Based Education. Also, the Excel sheets that needs to be uploaded have to follow a particular syntax and format as specified by the InPods. Otherwise, the data will not be successfully uploaded on the InPods platform. This is one area where the InPods team needs to simplify the uploading task for the faculty members as it is difficult to expect faculty from various backgrounds to follow the exact syntax and formatting style needed for uploading purposes. Also, the faculty member or the Course IC has to upload four Excel files on the InPods platform in order to perform the CO-PO attainment analysis of each section. The first Excel file is for homework/quiz marks, the second Excel file is for laboratory reports marks, the third Excel file is for midterm examination question-wise marks, and the fourth Excel file is for end-term examination question-wise marks. This is another area where the InPods team needs to rework on their software suite to accept the uploading of just one Excel file comprising of all the assessment marks for a particular section.

Moreover, it is difficult to precisely capture the question-wise marks data for all the 25 sections comprising of over 1400 students. This is really a challenging task for any faculty member given the amount of academic, administrative/committee, and research workload one may take. Therefore, we suggest capturing the question-wise marks data of only a certain number of students samples from each section. For example, 3 to 5 samples each of high, average, and low performers from every section of a given course may be considered. Therefore, for each section we will have 9 to 15 samples. For 25 sections as in our case we will have 225 to 375 samples, which is enough for analyzing the CO-PO attainment for a given course. In this way, we can save the faculty time and effort and the faculty members may use their time for other academic and research related activities. As the volume of students question-wise sample data that needs to be recorded in Excel sheets is less, this will increase the precision with which students' question-wise marks data is captured and also increases the accuracy of the CO-PO attainment analysis and the analysed results may be much more reliably used for suggesting further continuous improvements to the course for the benefit of the next batch of enrolled students. It should be noted that the Digital Design course is offered as Digital Electronics course with course code ECE2002 for the ECE students with the same lecture and laboratory content as the Digital Design course. But, the laboratory experiments are conducted on digital trainer kits for the ECE students and no software simulation tools are used.

The FCAR tool is more suitable for analyzing courses with less student enrolments. On the other hand, the InPods tool is suitable for analyzing courses with large student enrolments. The FCAR tool may also be easily implemented using Excel spreadsheets. However, InPods has a dedicated software suite to monitor the CO-PO attainment during a student's undergraduate degree cycle. Customization may easily be incorporated in the FCAR tool whereas only few things such as threshold and target set for a particular course are customizable on the InPods platform at the front-end. In order to achieve a greater level of customization, the client has to contact the InPods administrators who will incorporate the necessary customization at the back-end depending on the clients requirement. Moreover, InPods is also extensively used at our university for the moderation and generation of midterm and end-term examination question papers of various courses.

III. Conclusion

Using the InPods platform, a pilot study was conducted in this paper by analyzing the question-wise marks data of about 120 students (8.5%) out of over 1400 students enrolled in the Digital Design course during the spring semester of the Academic Year $2022 - 23$. It is significant to note that none of the 5 course outcomes were attained at the expected target level of 60% each by the 2 sections comprising of about 120 students out of 25 sections comprising of over 1400 students. In other words, there was a low level of attainment at the expected target level of 60% in all the 5 course outcomes of the Digital Design course. Using the InPods platform, presently we could only analyze whether the expected target of 60% students from each section (i.e., 36 students out of 60 students) was attained or not with respect to the expected threshold marks of 60% of the total marks (i.e., 120 marks out of 200 marks). The present study leaves us with the following questions to be answered. Is the Digital Design course introduced too early in the curriculum that the students performed so badly in general and none of the 5 COs were attained? Is it appropriate to introduce this course at the freshman-level instead of at the sophomore-level? The

Digital Design course is a prerequisite to many other courses. Is it necessary to have a course at the freshman-level which acts a prerequisite to the Digital Design course itself? How to motivate students majoring in B.Tech. programs such as Artificial Intelligence, Big Data, Blockchain, Cyber Security, Data Science, DevOps, Internet of Things, Machine Learning, Robotics, etc. to take the Digital Design course seriously so that they can perform well considering the fact that this course is offered by the ECE Department and students often view this course as an out-of-department course as it is usually taught by the ECE faculty members. Also, the precise question-wise marks collection of the midterm and end-term examinations of the students holds the key for reaping the full benefits of a successful Outcome-Based Education implementation using a modern and powerful learning management system such as InPods.

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