Mapping Student Learning Outcomes through Competencies and Key Performance Indicators

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Abstract: *Curriculum Development* is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the educational system. The first step in curriculum development is to define the aim, objectives and outcomes for an educational program. Student learning outcomes must be developed for each educational program, for each course in the program and for each module in the course. The student learning outcomes must be aligned within a hierarchy of outcomes. The program outcomes are more generic high-level goals that are not directly measurable. Directly mapping course outcomes with program outcomes is an abstract process and make it tough to map outcomes as well as assessment. Performance indicators are more specific statements when compared to program outcomes. Mapping course outcomes and program outcomes using competencies and key performance indicators makes course outcome attainment measurable and hence the program outcome assessment becomes measurable. This paper focuses on developing a general procedure for mapping course outcomes with program outcomes using the competencies and performance indicators defined for each program outcome. A case study is presented on the undergraduate engineering course *Digital Logic Design* to demonstrate the effectiveness of the proposed approach.

Keywords: outcome-based education, student learning outcomes, mapping learning outcomes, competencies, key performance indicators.

1. Introduction

Curriculum is a continuous and iterative process to plan for the educational activities over a period of time. Continuous societal/technical/technological progression is leading to industry-institute gap. Knowledge is growing and information is changing extremely quickly, creating new possibilities. Hence, curriculum must be redesigned through time to respond to these demanding issues.

The terms curriculum development and curriculum design can be defined as follows.

Curriculum Development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the educational system.

Curriculum Design refers to the organization and structuring of curriculum components.

In some literature, curriculum development and curriculum design are considered to be synonymous.Curriculum development is required to organize and select the content of study, students learning experiences and other relevant activities helping students to acquire the goals and objectives. The curriculum development process includes the tasks of planning, implementing, and evaluating the learning experience for an educational program.

The four questions that need thrived upon in the curriculum development process is as follows (Tyler 2013). Accordingly, the four components of curriculum are as follows.

1) What is to be achieved? (Aims, Objectives and Outcomes)
2) What content is to be provided? (Course Content)
3) Which instructional strategies, resources and activities should be employed? (Instructional Design or Design of Learning Experiences)

4) Which methods and instruments should be used to appraise the results of the curriculum? (Assessment and Evaluation)

2. Taxonomy

As per the definitions provided by the National Skill Qualification Framework (NSQF) (MHRD India 2019) -

Competency is a statement of the "desired knowledge, skills, attitude of student graduating from the course/ program". As per NSQF, competence is defined as "the proven ability to use acquired knowledge, skills and personal and social abilities, in discharge of responsibility roles".

As defined by International Engineering Alliance (IEA)(ABET 2019) -

A *professionally competent* person has the "attributes necessary to perform the activities within the profession or occupation to the standards expected in independent employment or practice".

The *key performance indicators* (KPIs or simply called as PIs), are the "actions on the part of the candidate that demonstrate competence". PIs represent the "knowledge, skills, attitudes or behavior students should be able to demonstrate by the time of graduation that indicate competence related to the outcome".

Program Outcomes (POs) are more generic high-level goals that are not directly measurable. PIs are more specific statements when compared to POs. PIs specify the most detailed activity a student must perform to demonstrate his/her level of learning related to a PO. PIs are highly specific and measurable statements pertaining to activities a student shall perform through the educational program. PIs are to be developed specific to the engineering program under consideration and are developed in terms of KSAs (Knowledge, Skill, Attitude). Defining PIs

- Will allow the instructors, students, evaluators to have a common and clear interpretation of what is the expected performance from the graduates/students in terms of specific activities.
- Will allow a more approachable technique to define correlation levels between course content, COs and POs.
- Will allow a more accurate and unambiguous assessment of POs.

For each PO a set of competencies should be developed. Further, for each competency a set of PIs should be developed. For eachPO, three to five competencies may be developed and for each competency two to five PIs may be developed. Sample competencies and relevant PIs for undergraduate engineering (mechanical engineering, computer science/information science engineering) programs may be referred in (AICTE India 2019).

3. General Structure of Student Learning Outcome Statement

The generic structure of student learning outcome statements is shown in Fig. 1(Baker 2019). The optimal length of an outcome statement is 200 to 250 characters.

1. *Condition* - is most generally stated as "After successful completion of the program/course/module, students will be able to".
2. *Action* – describes the performance of the students. Action verbs of domains of learning (cognitive,

psychomotor, affective domains) are used here to specify what action students will be able to take in terms of KSAs.

3. *Criterion* – describes what students will know/do. This is generally specified by linking the action with the content delivered in the program/course/module.
4. *Context/Application* – describes the context/scope/scenario/application in which student can act. Generally, this part of the SLO statement starts with the word "for" or "to". This part may be taken as optional for SLO statements relating to LOTS. For SLO statements relating to HOTS this part must be considered mandatory so as to define the limit of applicability of the students' skill to a context. This part makes the SLO statement complete and makes it meaningful, realistic and measurable

Fig. 1 Generic structure of Student Learning Outcome Statement

4. Developing Course Outcomes

Once the syllabus for a course is prepared, Course Outcomes (COs) must be prepared. While developing COs for a course, the following general procedure may be followed for writing CO statements to effectively reflect the content of the course and the KSAs being imparted in students through the course (Fig.2).

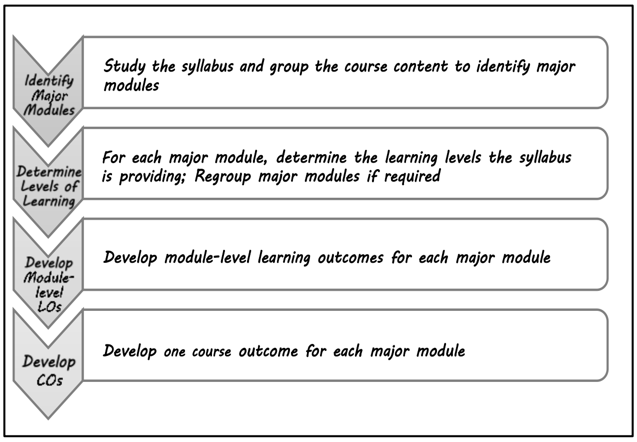

Fig. 2 General Procedure for Developing COs

The syllabus for a course is most generally divided into 4 or 5 units (some institutions may call it as modules).

1) *Identify Major Modules*: Study the syllabus of the course and group the content in syllabus to identify major modules. Grouping of content can be done as follows.
   a) Multiple units providing discussion on the same topic in continuity from basics to advanced levels of complexity can be treated as single major module. A unit providing discussion on two different topics may be considered as different major modules.
   b) Identification of major modules can also be done by identifying key words of interest in the course that provide distinctiveness to the course from other courses. Then, group content in syllabus accordingly.
2) *Determine Levels of Learning*: For each major module that is identified as in step (1), determine the learning levels the syllabus is providing. Mapping syllabus of each major module to levels of learning may be done using the following procedure. For each major module,

a) List out the sample questions at all the possible learning levels.

b) Map the questions to the levels of learning and group the questions based on the levels of learning. A major module may have content to support different levels of learning.

c) Regroup major modules according to Levels of Learning if required. In a major module, if the syllabus of different major topics is providing different levels of learning, then the major modules may be further divided into sub-modules.

3) *Develop Module-level Learning Outcomes*: Learning outcomes shall be written for each major module (module-level learning outcomes). These are required to clearly and explicitly state the learning outcomes at module level. The generic structure of SLO statement as shown in Fig. 1may be followed for developing these statements. Number of learning outcomes for each major module may be limited to three/four.

4) *Developing Course Outcomes*: Once the module-level learning outcomes are prepared, taking them as reference, write one CO for each major module. The generic structure of SLO statement as shown in Fig. 1may be followed for developing CO statements. A CO may contribute to multiple POs i.e, one CO may be mapped to multiple POs thus supporting a one-to-many CO-PO mapping model.

While developing CO statements for a course, the followinggeneral guidelines may be followed.

a) The majority of the COs should be in the Higher Order Thinking Skills (HOTS) levels of the cognitive skills domain – Analyze, Evaluate, and Create(Anderson 2001).

b) Ensure that the number of COs is not more than six (as per National Board of Accreditation guidelines)(NBA 2016).

c) Each CO statement starts with an action verb to specify the action student will be able to take in terms of domains of learning.

d) CO statements must be written using active verbs where the student is the subject.

e) Each CO statement should focus on what students will know and be able to do. Select a suitable action verb that best describes the actions students will be able to take after learning specific content. Action Verb should specify the type and level of domain of learning.

f) The CO statements must be clearly and crisply written so as to make them achievable and measurable.

g) The CO statements must not describe the process of learning or what student learns, but what he will be able to do after learning. Do not use words as know, understand, learn etc.

h) Avoid usage of vague action verbs that do not support proper assessment or measurement of students' performance. Ex: know, understand, appreciate, be aware of, learn, comprehend, become familiar with etc.

i) Action verbs under Bloom's cognitive level (Anderson 2001) must be avoided as they do not support the assessment of students' performance in terms of KSAs.

j) Use only one action verb in each CO statement. If the major module is providing multiple levels of learning, use the action verb related to the highest levels of learning provided by that major module.

k) Use language relevant to the educational program in the "Content" and "Modifier" sections to write effective CO statements.

l) CO statements should showcase the scope and distinctiveness of the course.

m) Verify that the CO statements are aligned with the POs by developing course-level curriculum maps.

n) Developing COs must be a collaborative process of faculty and students. Finally, the COs must be approved in Board of Studies.

5. Case Study

The example discussed here is on the course offered by undergraduate engineering (CSE, IT, ECE, EEE) program.

The general procedure proposed in the previous sections is presented in this section for developing course outcomes of thetheory course Digital Logic Design. Consider unit 1 comprising of Number Systems, Boolean Algebra, Digital Logic Gates, Binary Arithmetic, unit 2 Minimization and Implementation of Digital Logic, unit 3 Combinational Circuits, unit 4 Synchronous Sequential Circuits, unit 5 Programmable Logic Devices.

A. Identify Major Modules

The syllabus of the course is studies and the keywords of interest are identified and major modules are determined as

- Binary Arithmetic & Boolean Algebra (unit 1).
- Basic Digital Circuit Minimization and Implementation (units 1, 2).
- Combinational & Synchronous Sequential Circuits, PLDs (units 3, 4, 5).

B. **Determine Levels of Learning**

For each major module that is identified, learning levels the syllabus is providing are determined. Table 1 shows the mapping of content of major modules with levels of learning (Bloom's Cognitive Levels). Also, mapping to performance indicators is performed.Table 2 shows the justification and process used to map the major module content to Bloom's cognitive levels of learning and performance indicators. Table 3 shows the Summary of PIs from AICTE Examination Reforms 2018 for PO1, PO2, PO3(AICTE 2019). Table 4 shows the major modules and the mapped levels of learning summarized from Table 1.

Table 1 Mapping Major Modules Contentwith Learning Levels and PIs

Module No.	Sample Questions	Highest Bloom's Cognitive Level Mapped	PI Mapped	PO Mapped	Assessment Tool
Major Module 1: Binary Arithmetic & Boolean Algebra					
MM1.1	✓ State Boolean Laws ✓ What are the three forms of binary number representation	BL1	PO1	PO1	Quiz
MM1.2	✓ Represent number $(X)_{10}$ in base B ✓ Perform number base conversion $(X)_{B1} = (\ )_{B2}$ ✓ Find complements of numbers ✓ Represent number $(X)_{10}$ in binary (sign-magnitude, 1's complement, 2's complement) ✓ Perform arithmetic operations on given numbers using sign-magnitude/1's complement/2's complement ✓ Simplify the following Boolean expression to a minimum number of literals using Boolean Algebra ✓ Prove the equality of the Boolean expressions ✓ Differentiate between canonical and standard forms of Boolean expressions ✓ Derive Boolean expression for the truth table ✓ Obtain the truth table of the Boolean function	BL2	1.3.1	PO1	Written Exam
Major Module 2: Basic Digital Circuit Minimization and Implementation					
MM2.1	✓ Represent the truth tables of the logic gates ✓ Which logic gate can be used to compare two binary bits?	BL1	PO1	PO1	Quiz
MM2.2	✓ Implement the Boolean expression using logic gates ✓ Express the Boolean function in SOP form ✓ Convert between canonical forms ✓ Express the complement of the following function in sum-of-min terms form ✓ Explain the degenerate and non-degenerate forms of two-level logic implementation	BL2	1.3.1	PO1	Written Exam
MM2.3	✓ Implement the following Boolean function ✓ Derive Boolean expression for the logic diagram ✓ Find the prime implicants for the following Boolean function ✓ Simplify the following Boolean expression using K-Map method ✓ Show that the dual of the exclusive-OR is also its complement	BL3	1.3.1	PO1	Written Exam

Module No.	Sample Questions	Highest Bloom's Cognitive Level Mapped	PI Mapped	PO Mapped	Assessment Tool
MM2.4	✓ Draw logic diagram for the Boolean function using 2-level implementation ✓ Draw logic diagram using only 2-input NOR gates to implement the following Boolean function ✓ Draw multi-level circuit for the following Boolean function	BL4	1.3.1, 2.3.1	PO1, PO2	Written Exam
Major Module 3: Combinational & Sequential Circuits, PLDs					
MM3.1	✓ What is a multiplexer? ✓ What will be number of outputs for a decoder with N inputs?	BL1	PO1	PO1	Quiz
MM3.2	✓ Describe the functionality of Encoder, Decoder, Multiplexer etc ✓ Describe the functionality of Flip-flop, latch etc	BL2	1.3.1	PO1	Written Exam
MM3.3	✓ Tabulate the truth table for ROM given Boolean functions ✓ Tabulate the PLA programming table for Boolean function	BL3	1.3.1	PO1	Written Exam
MM3.4	✓ Analyze the combinational circuit and derive Boolean expression ✓ Analyze the sequential circuit and derive the state table and state diagram ✓ Analyze the sequential circuit and tabulate the characteristic table, excitation table, derive the characteristic equation ✓ Construct a ROM ✓ Derive the PLA programming table for the combinational circuit	BL4	1.3.1, 2.2.2	PO1, PO2	Written Exam
MM3.5	✓ Formulate Boolean function and design combinational circuits for arithmetic operations ✓ Formulate Boolean function and design combinational circuits for basic applications ✓ Design a sequential circuit given the flip-flop input equations and circuit output equation ✓ Design counters, shift registers for basic applications ✓ Design sequential circuits for basic applications ✓ Design PLA circuits to implement basic applications	BL4	1.3.1, 2.2.2, 2.3.1, 3.2.2	PO1, PO2, PO3	Written Exam
MM3.6	✓ Design digital circuits for engineering problems	BL4	1.3.1, 2.1.1, 2.2.2, 2.2.3, 2.2.4, 2.3.1,	PO1, PO2, PO3	Mini-project (Project Based Learning)

Module No.	Sample Questions	Highest Bloom's Cognitive Level Mapped	PI Mapped	PO Mapped	Assessment Tool
			2.4.2, 2.4.3, 2.4.4, 3.2.2, 3.4.2, 3.4.3		
Note: While mentioning Bloom's Cognitive Level Mapped, only the highest level is explicitly listed here. If a higher cognitive level is mapped, then all the lower cognitive levels are also applicable. For example, MM 3.4 is explicitly mapped to BL4. Then MM3.4 is implicitly mapped to BL3, BL2. Questions of MM3.4 in exam may be given to students at BL4, BL3 and BL2 levels.					

Table 2 Summary of KPIs from AICTE Examination Reforms 2018 (For PO1, PO2, PO3)

✓ *1.1.1* – Apply mathematical techniques such as discrete structures, algebra, statistics, numerical techniques ✓ *1.1.2* – Apply knowledge of probability, statistics, queuing theory ✓ *1.2.1* – Apply knowledge of natural sciences ✓ *1.3.1* - Apply knowledge of engineering fundamentals ✓ *1.4.1* - Apply knowledge of CSE fundamentals ✓ *2.1.1* – Identify problems, identify objectives, formulate problem statements ✓ *2.1.2* – Identify alternative processes/modules/algorithms ✓ *2.1.3* – Identify mathematical algorithmic knowledge ✓ *2.2.1* – Identify interconnected subsystems ✓ *2.2.2* – Identify functionalities and computing resources ✓ *2.2.3* – Identify existing solutions/methods ✓ *2.2.4* – Compare existing solutions/methods to select suitable solution/method ✓ *2.2.5* – Compare alternative processes to select suitable process ✓ *2.3.1* – Formulate and interpret model ✓ *2.3.2* – Identify design constraints ✓ *2.4.1* – Apply engineering mathematics to implement solution	✓ *2.4.2* – Perform experimentation, interpret and analyze results; use tools ✓ *2.4.3* – Identify limitations of proposed solution ✓ *2.4.4* - provide valid conclusions ✓ *3.1.1* – Define problem statement, objectives, scope ✓ *3.1.2* – Identify, document system requirements ✓ *3.1.3* – Review literature, state-of-art of the solutions ✓ *3.1.4* – Choose suitable industry standards ✓ *3.1.5* – Explore system requirements in societal context ✓ *3.1.6* – Develop SRS ✓ *3.2.1* – Explore existing design alternatives ✓ *3.2.2* – Develop alternative design solutions to conform functional requirements ✓ *3.2.3* – Identify non-functional requirements to evaluate alternative design solutions ✓ *3.3.1* – Evaluate alternative design solutions ✓ *3.3.2* – Select a best design solution ✓ *3.4.1* – Refine design solution ✓ *3.4.2* – Implement solution and integrate modules ✓ *3.4.3* – Verify functionalities and validate design

Table 3 Justification and process to map major module content to learning levelsand performance indicators

<table>
<tr><th>Reasoning for Bloom's Cognitive Level Mapping</th><th>Reasoning for PI Mapping</th></tr>
<tr><td colspan="2">Modules: MM1.1, MM2.1, MM3.1</td></tr>
<tr><td>To answer these questions, students have to
✓ Remember(BL1) what they have learned through course.</td><td>Are mapped to PO1 because they provide basics of the course to the students.</td></tr>
<tr><td colspan="2">Modules: MM1.2, MM2.2, MM3.2</td></tr>
<tr><td>To answer these questions students must have
✓ Understood (BL2) the relevant concepts through course.</td><td>R1. Are mapped to PO1 because to answer these questions students should be able to solve problems by applying their knowledge of engineering fundamentals to some extent what they learned through the course.
R2. They are mapped to 1.3.1 because digital logic design is a core engineering subject.
R3. They are not mapped to 1.1.1, 1.1.2, 1.2.1, 1.4.1 because application of those fundamentals is not required to answer these questions.</td></tr>
<tr><td colspan="2">Modules: MM2.3, MM3.3</td></tr>
<tr><td>To answer these questions students must have
✓ Understood the relevant concepts through course (BL2).
✓ Apply their knowledge solve problems (BL3).

The problems considered here, need a higher order thinking skill, not just mere understanding.

Note: Among BL2 and BL3, BL3 is the higher cognitive level. Hence, in the BL mapping only BL3 is explicitly specified.</td><td>R1.
R2.
R3.

Note: Answering these questions may involve analysis, but to a very minimal extent, so it is not mapped to PO2. Generally, these problems are simple which involve direct application of knowledge and do not involve much analysis to be done by the student. Hence, BL/PO mapping is limited up to BL3/PO1.</td></tr>
<tr><td colspan="2">Example:
Question: Simplify the following Boolean expression using K-Map method.

Reasoning: To answer this question student must
✓ Have understood the concepts of Boolean expressions and K-map Minimization Methods (BL2, 1.3.1).
✓ Use gained knowledge of these concepts, apply to simplify any given Boolean Expression (BL3, 1.3.1).</td></tr>
<tr><td colspan="2">Modules: MM2.4, MM3.4</td></tr>
</table>

To answer these questions students must have ✓ *Understood* the relevant concepts through course (*BL2*). ✓ *Analyze* the given problem *(BL4)* ✓ Solve it by *applying* their *knowledge (BL3)*. The problems considered here, need analysis of problems, not just application of knowledge. Note: Among *BL2*, *BL4* and *BL3*, *BL4* is the higher cognitive level. Hence, in the BL mapping only *BL3* is explicitly specified.	R1. R2. R3. R4. Are mapped to *PO2* because to answer these questions students should analyze the problem to solve it. Note 1: As assessment tool is written exam, students' analytical skills cannot be tested to a greater extent.
Example: *Question:* Analyze the combinational circuit and derive Boolean expression *Reasoning:* To answer this question student must ✓ Have understood the concepts of Boolean Functions, Minimization Methods, Combinational circuits *(BL2/1.3.1)*. ✓ Analyze the given circuit to identify variables and relationships between them *(BL4/2.3.1)*. ✓ Express the variables as Boolean variables and formulate Boolean Functions to identify circuit functionality (*BL4/2.2.2*).	
Modules: MM3.5	
To answer these questions students must have ✓ *Understood* the relevant concepts through course (*BL2*). ✓ *Analyze* the given problem *(BL4)* ✓ Solve it by *applying* their *knowledge (BL3)*. The problems considered here, need analytical and basic design skills. Note: Among *BL2*, *BL4* and *BL3*, *BL4* is the higher cognitive level. Hence, in the BL mapping only *BL3* is explicitly specified.	R1. R2. R3. R4. Are mapped to *PO2* because to answer these questions students should analyze the problem to solve it. R5. Are mapped to *PO3* because to answer these questions students should design a digital circuit to solve the given problem. Note 1: As assessment tool is written exam, students' design skills cannot be tested to a greater extent.
Example: *Question:* Design PLA circuits to implement basic applications. *Reasoning:* To answer this question student must ✓ Have understood the concepts of Boolean Functions, Minimization Methods, Combinational & Sequential Circuits, PLA circuits *(BL2/1.3.1)*. ✓ Analyze the given problem; identify required functionalities *(BL4/2.2.2)*. ✓ Identify variables and relationships between them, express the variables as Boolean variables and formulate Boolean Functions (*BL4/2.3.1*). ✓ Design digital circuit, and tabulate function tables to provide a solution to the given problem *(BL3/1.3.1, BL4/3.2.2)*. Note:	

<table>
<tr><td colspan="2">✓ Not mapped to 2.1.1 because instructor is identifying, formulating a problem and given to students.
✓ Not mapped to 2.4.1, 2.4.2, 2.4.3, 2.4.4 because students are only providing solution, they are not implementing/testing the solution (as assessment tool is written exam)</td></tr>
<tr><td colspan="2">Modules: MM3.6</td></tr>
<tr><td>To answer these questions students must have
✓ Understood the relevant concepts through course (BL2).
✓ Analyze the given problem (BL4)
✓ Solve it by applying their knowledge (BL3).

Note 1: Among BL2, BL4 and BL3, BL4 is the higher cognitive level. Hence, in the BL mapping only BL3 is explicitly specified.

Note 2: As this is an introductory level subject, students are expected to solve engineering problems with Low/Medium level complexity. They are not expected to solve complex engineering problems. Hence, cognitive level is limited to BL4 instead of BL6.</td><td>R1.
R2.
R3.
R4.
R6. Are mapped to PO3 because students should design a solution to the problem.

Note: As assessment tool is Mini-project, students' analytical & design skills can be assessed to a greater extent.</td></tr>
<tr><td colspan="2">Example:

Question: Design digital circuits for engineering problems

Reasoning: Student must

✓ Have understood the concepts of Boolean Functions, Minimization Methods, Combinational & Sequential Circuits, PLA circuits (BL2/1.3.1).

✓ Identify a problem; formulate the problem (BL4/2.1.1).

✓ Analyze the given problem; identify required functionalities (BL4/2.2.2).

✓ Identify variables and relationships between them, express the variables as Boolean variables and formulate Boolean Functions, tabulate function tables (BL3/1.3.1, BL4/2.3.1).

✓ Identify available digital circuits (ICs) for providing partial functionalities (BL3/1.3.1, BL4/2.2.3).

✓ Compare identified digital circuits (ICs) suitable for the problem (BL3/1.3.1, BL4/2.2.4).</td></tr>
</table>

- ✓ Design digital circuit to solve problem *(BL3/1.3.1, BL4/3.2.2)*.
- ✓ Implement digital circuit *(BL3/1.3.1, BL4/3.4.2)*.
- ✓ Test the digital circuit; interpret and analyze results *(BL3/1.3.1, BL4/2.4.2).*
- ✓ Provide valid conclusions to prove functionality correctness *(BL3/1.3.1*, *BL4/2.4.4/3.4.3)*.
- ✓ Identify limitations of proposed solution *(BL4/2.4.3)*.

Table 4 Major Modules and Mapped Levels of Learning

Major Module No.	Major Modules	Levels of Learning (Bloom's Cognitive Levels)
MM1	Binary Arithmetic & Boolean Algebra	BL1 (Remember) BL2 (Understand)
MM2	Basic Digital Circuit Minimization and Implementation	BL1 (Remember) BL2 (Understand) BL3 (Apply) BL4 (Analyze)
MM3	Combinational & Synchronous Sequential Circuits, PLDs	BL1 (Remember) BL2 (Understand) BL3 (Apply) BL4 (Analyze)

C. **Develop Module-Level and Course Level Outcomes**

Once the major modules are identified and are mapped to levels of learning and POs, learning outcomes are developed for each major module (module-level learning outcomes). Table 5 shows the major modules and the respective module-level learning outcomes. Table 6 shows the major modules and the respective course outcomes. Table 7 shows the course-level curriculum map showcasing the program outcomes achieved through the course.

If the course-PO mapping is not up to the expected level, the course syllabus must be refined and the process is to be iterated until satisfactory program outcomes are achieved through the course.

Table 5 Major Modules and the Respective Module-Level Learning Outcomes

Major Module	Module-level Learning Outcomes
MM1. Binary Arithmetic & Boolean Algebra	MLO1.1 Demonstrate knowledge on number systems and number base conversions. MLO1.2 Demonstrate knowledge on binary number representations to carry out binary arithmetic. MLO1.3 Apply Boolean laws to minimize Boolean expressions.
MM2. Basic Digital Circuit Minimization and Implementation	MLO2.1 Implement Boolean functions with digital logic circuits. MLO2.2 Apply K-Map method to minimize digital logic circuits. MLO2.3 Analyze and design digital logic circuits to solve basic problems.
MM3. Combinational & Synchronous Sequential Circuits, PLDs	MLO3.1 Demonstrate knowledge on fundamental concepts of combinational circuits, sequential circuits and PLDs to solve basic problems. MLO3.2 Formulate problems and design digital logic circuits to solve engineering problems.

Table 6 Major Modules and the Respective Course Outcomes

Major Modules	Course Outcomes
MM1. Binary Arithmetic & Boolean Algebra	**CO1.** Demonstrate knowledge on binary arithmetic and Boolean algebra to realize the fundamentals of digital systems.
MM2. Basic Digital Circuit Minimization and Implementation	**CO2.** Analyze Boolean functions to implement using digital logic circuits.
MM3. Combinational & Synchronous Sequential Circuits, PLDs	**CO3.** Design digital logic circuits to solve engineering problems.

Table 7 Course Outcomes and their Alignmentwith Program Outcomes

Course: Digital Logic Design												
Course Outcome	**Program Outcomes**											
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	✓											
CO2	✓	✓										
CO3	✓	✓	✓									

6. Conclusions

For making program outcomes measurable, each program outcome is further demarcated by defining distinct competencies and key performance indicators that a student must demonstrate to achieve the outcome. Competencies are the desired knowledge, skills, attitude of student graduating from the course/ program. Performance indicators specify the most detailed activity a student must perform to demonstrate his/her level of learning related to a program outcome. Performance indicators are highly specific and measurable statements pertaining to activities a student shall perform through the educational program. This paper focused on developing a general procedure for mapping course outcomes with program outcomes using the competencies and performance indicators defined for each program outcome. A case study is presented on the undergraduate engineering course *Digital Logic Design* to demonstrate the effectiveness of the proposed approach.

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