

CASE STUDY

Recent development in undergraduate computer engineering education: Indian scenario

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India, being a developing country, is also growing at lightning speed, where technology also plays an important role. Software and hardware are intricately linked as far as information systems are concerned, and as a result, there is considerable need for a rapidly developing field of computer-linked technology in our country. Due to their potential experience in data science, big data, artificial intelligence, and machine learning, the aspirants of computer engineering have good expected pay, thus they need proper education and training in software development, and system database administration to keep pace with technology. In the Computer Science and Engineering (CSE) domain, a vigorous system curriculum development process is basic and sanctifies the institutionally quirky and rapidly evolving field of Computer Science from programming and networking to the newest areas in the discipline. Following the All India Council for Technical Education (AICTE) curriculum, this study speaks of the Regulation 18 (R18) curriculum of one such autonomous engineering institute, located in West Bengal. A comparative background study analyzing curricula from several universities to assess variations and best practices was performed. This analysis is especially suited to self-financed institutions, as more than 80% of India's 4000+ engineering colleges are owned by the private sector. According to Outcome-Based Education, the R18 curriculum is to include all core CSE subjects with a wide allowance for flexibility in the teaching-learning process as per the norms of AICTE. Certain shortcomings were pointed out in the feedback from stakeholders; hence, it will drive the changes in the present Regulation 21 (R21) curriculum under the New Education Policy (NEP) 2020. This paper also gives a comparative study of the two curricula, R18 and R21, and discusses results in detail with graphs that can be interpreted easily. It helps understand how curricula evolve to become synchronized with industry requirements, endowing graduates with requisite competencies in the shifting paradigm of technology.

Keywords: AICTE, CSE, Regulation 18, R21, NEP 2020, Systematic Curriculum Development

Introduction

The quality of education (1–3), including teaching and learning in technical subjects, depends on a number of factors irrespective of the discipline. Here the major focus areas to consider are socially and industrially relevant outcome-based curriculum for holistic development of the students, qualified and motivated teaching staff, a well-organized academic system, an effective and practical

industry internship program, and students' evaluation based on expected outcomes. So it is imperative that a model curriculum must be prepared for each discipline starting from its undergraduate (UG) degree course. Accordingly, in India, All India Council of Technical Education (AICTE) (1) constituted teams of subject experts from academics and industry and formalized a suggestive curriculum for each discipline which became acceptable to all universities/boards of technical education and autonomous engineering

institutions of the country as there were provisions to exercise flexibility in developing their respective curriculum with necessary readjustment of courses, but within the stipulated credit limit. As per AICTE guide lines (https://www.aicte-india.org/sites/default/files/Model_Curriculum/Updated-AICTE%20-%20UG%20CSE.pdf), mandatory internships had been introduced in the implemented curriculum so as to equip the engineering students with industry experiences in a real environment of a suitable industrial infrastructure or organization for their practical training and necessary understanding. By considering the latest trends of industry and the market requirements, the Computer Science and Engineering (CSE) (2–6) appears to be a promising career choice for tech-savvy individuals who are fascinated by the latest computing advancements. The field offers excellent job prospects and high earning potential. According to the U.S. Bureau of Labor Statistics, computer and information technology (IT) occupations are projected to grow at a faster-than-average rate of 11% from 2022 to 2032 (<https://www.bls.gov/ooh/computer-and-information-technology/home.htm>) whereas it is projected to grow at 13% from 2020 to 2030 (<https://www.upgrad.com/blog/scope-of-computer-science/>). The growth of the Indian computer industry appears to be no exception. So Computer Engineering UG curricula for an AICTE-approved, NBA-accredited, autonomous, and self-financed engineering college (5) are chosen in the present work as a sample to study and discuss its current status in Indian engineering education, highlighting the reforms introduced in line with the requirements of the computer industry. The purpose of this research work is to evaluate how well-defined academic curriculum learning satisfies industry requirements.

CSE curriculum

B. Tech. in CSE is an academic program where the study period covers four years with eight semesters in almost all countries of the world, including India. Being one of the most favorite courses among engineering students, this course basically integrates the fields of computer engineering and computer science (2–5). It emphasizes the basics of computer programming and networking along with related interdisciplinary electronic and electrical circuitry. The broad major topics covered in the course are computation, algorithms, programming languages, program design, computer software, and computer hardware, which expose the learners in different aspects of computing, from the design of individual microprocessors, personal computers, and supercomputers to circuit designing and even writing software that empowers them (<https://www.shiksha.com/engineering/computer-science-engineering-chp>).

Here it may be mentioned that IT professionals who understand the trends in computing remain competitive for the best career opportunities, exploring recent computing developments and trends in IT with artificial intelligence (AI), Cyber Security, and robotics. Inclusion of Data Science and Business Analytics, AI and Machine Learning (ML), Project Management and Cloud Computing creates opportunities for entrepreneurs to start up their business careers and enterprises with fast-track leadership in the areas of Software Development, Agile and Scrum IT Services and Architectures, Digital Marketing, and Big Data Analytics, etc., (7, 8) maintaining the quality management.

Accordingly, a standard curriculum of CSE of an autonomous NBA-accredited engineering institute located at North 24 Parganas, West Bengal, as a sample, is highlighted here, which may help to understand the course to the fullest. Subjects and credits included under Regulation 18 (R18, first batch graduated in 2022) were discussed at the beginning (Tables 1 and 2). This academic curriculum framework shows the academic structures and credit distribution followed by several autonomous engineering colleges in the southern part of West Bengal.

B. Tech. in Computer Science and Engineering – course design

The structure of the UG Program (R18) in CSE consisted of essentially the following categories of courses whose credit breakup was given in Table 1 (https://www.aicte-india.org/sites/default/files/Model_Curriculum/Updated-AICTE%20-%20UG%20CSE.pdf, www.gnit.ac.in).

The course covered basic science and engineering science with focus on their fundamentals, humanities and social science courses including Universal Human Value course along with emphasis on management skills, discipline-specific core courses and flexible electives, both professional and open, from the disciplines and cross disciplines respectively. Emphasis was given on emerging areas within the cumulative structure distributed among 160 credit points in R18 and with slight modification of 163 points under R21, as per the guideline framed by AICTE (https://www.aicte-india.org/sites/default/files/Model_Curriculum/Updated-AICTE%20-%20UG%20CSE.pdf). Each course contained well-defined learning objectives and outcomes (6, 9–13).

Additional features of the curriculum

It includes.

- Introduction of student induction program.

TABLE 1 | UG CSE course structure under R18 as per the guideline of AICTE.

Sl. no.	Category	Credit allocation as per AICTE (R18)	Credit allocation as per autonomy (R18)
1	Humanities and Social Sciences including Management courses (HSMC)	12*	9
2	Basic Science courses (BSC)	25*	25.5
3	Engineering Science courses, including workshop, drawing, basics of electrical/mechanical/computer, etc. (ESC)	24*	26
4	Professional Core Courses (PCC)	48*	50.5
5	Professional Elective courses relevant to chosen specialization/branch (PEC)	18*	19.5
6	Open subjects—Electives from other technical and/or emerging subjects (OEC)	18*	15
7	Project work, seminar, and internship in industry or elsewhere (PR)	15*	14.5
8	Mandatory Courses [Induction Program, Environmental Sciences, Indian Constitution, Essence of Indian Knowledge Tradition, and other Co and extracurricular activities] (MC)	Non-credited	Non-credited
	Total	160	160

*Minor Variation is allowed by AICTE as per need of the respective disciplines.

- Summer internships which had been made mandatory for the students to understand the industry requirements and to have hands-on experience.
- A list of courses for mapping to their equivalent MOOCS courses in the form of SWAYAM/NPTEL/Equivalent, from where the students might learn to develop their problem-solving and outcome-based learning approaches to face the challenges in the future.
- Virtual labs for a few experimental courses on “Entrepreneurship and Start-ups” to encourage an entrepreneurial mindset.

Here, **Table 2** (Ref. (5)) highlighted the credit distribution of the Computer Science and Engineering Curriculum under Regulation 18 (R18).

Curriculum feedback survey for R18

After the implementation of the above curriculum, different stakeholders’ feedback was taken intermittently as they played a very crucial role in curriculum development (12–16) to cater the need of the society. The survey had been conducted amongst all the stakeholders connected to the progress of the academic institute, including the faculty and staff members of the department, students, alumni, society/industries, and the employers. In response to the specific set of queries on developed curriculum, a total of 150 feedbacks were collected from different stakeholders and enlisted in **Table 3**. An overall analysis is shown in **Table 4** (percentage-wise) and is represented in the form of a bar graph in **Figure 1**.

Significantly, such an analysis conducted on the passed-out first graduation batch of 2022, considering various common aspects of the Computer Science and Engineering curriculum framed under Regulation 18 (R18) following

AICTE’s directive, identified some lacunae or deficiencies in the implemented curriculum (see **Tables 3** and **4**). In general, engineering institutions in the country were found to lack sufficient resources, infrastructure, and qualified teachers, which couldn’t help in providing the quality of education and was found to fall short of the global standards due to such challenges. The course material was also found outdated and so failed to equip students with the necessary skills for the modern workplaces, and so that curriculum and theoretical approach had proven to be ineffective, for which the country might face a surplus of unemployed engineers in the near future. A more industry-focused practical approach has been designed to tackle this type of problem and to increase industry job opportunities.

Accordingly, it was found to be crucial to revamp the curriculum by introducing the relevant subjects in line with the global requirement and to ensure the state-of-the-art laboratories, which might provide the up-to-date knowledge and skills to meet the demands of the rapidly evolving tech industry. Regulation 21 (R21 continuing now) was planned to be introduced by AICTE, apprehending the outcome of the R18 curriculum from 2021 to 2022 B.Tech. batch onwards. Modification from R18 and year-wise (with two semesters) curriculum are detailed below in **Tables 5, 6, 7, 8, and 9**, respectively (https://www.aicte-india.org/sites/default/files/Model_Curriculum/Updated-AICTE%20-%20UG%20CSE.pdf) and analyzed from various perspectives to identify the changes made there from R18 and the logic behind such updates. These changes aim to include topics in the academic curriculum that match industry trends and new technological development.

Figure 2’s high “Strongly Agree” in proportion indicates that respondents strongly support the curriculum and syllabus. Although there is some variance in the Moderately Agree category, overall there is an increased trend that suggests a few concerns. With only minor variations, the disagree responses remain low, indicating limited

TABLE 2 | Highlights of R18 Computer Science and Engineering curriculum.

Sl. no.	Category with no. of papers	Papers as per R18 (Semester wise)
1.	HSMC (5)	English and Language Lab (Semesters 1 and 2, respectively) Economics for Engineers (Semester 4) Values and Ethics in Profession (Semester 7), Principles of Management (Semester 8)
2.	BSC (9)	Mathematics I and II (Semesters 1 and 2, respectively) and Mathematics III (Semester 3) Chemistry with Lab (Semester 2) Physics I and II with Lab (Semesters 1 and 3, respectively)
3.	ESC (12)	Basic Electrical/Electronic Engineering with Lab (Semesters 1 and 2, respectively) Engineering Mechanics (Semester 2) Engineering Graphics and Design (Semester 2), Workshop/Manufacturing Practice (Semester 1) Programming for Problem Solving with Lab (Semester 2), Circuit Theory and Network (Semester 3), Numerical Methods and Statistics with Lab (Semester 4)
4.	PCC (23)	Digital Electronics and Computer Organization with Lab, Data Structure with Lab, Programming with C++ (All in Semester 3) Computer Architecture with Lab, Design and Analysis of Algorithms with Lab, Formal Language and Automata Theory (All in Semester 4) Computer Graphics with Lab, Operating System with Lab, Data Base Management System with Lab (All in Semester 5) Computer Network with Lab, Microprocessors and Microcontrollers with Lab, Software Engineering with Lab (All in Semester 6) Design Lab (Semester 8)
5.	PEC (6)	Operations Research/Computational Geometry/Distributed Algorithms (Semester 5) Compiler Design/Computer Vision/Simulation and Modeling (Semester 6) Soft Computing with Lab/Natural Language Processing with Lab/Web Technology with Lab (Semester 7) Cloud Computing/Sensor Network and IOT/Cryptography and Network Security (Semester 7) Mobile Computing/Bio-informatics/Cyber Law and Security Policy/VLSI Design (Semester 8) Parallel Computing/Machine Learning/Real-Time Embedded System/Advanced Computer Architecture (Semester 8)
6.	OEC (5)	Object-Oriented Programming using Java with Lab/Multimedia Technology with Lab/Communication Engineering with Lab (Semester 5) Pattern Recognition/Distributed Operating System/Distributed Database (Semester 6) Data Warehousing and Data Mining/Digital Image Processing/E-commerce and ERP (Semester 6) AI with Lab/Robotics with Lab/Data Analytics with Lab (Semester 7)
7.	PR (15)	Project-IA, IB (Both in Semester 1), Project-II, Innovative Activity 1 (Both in Semester 2) Project-III, Innovative activities-II (Both in Semester 3), Project-IV, Innovative activities-III (Both in Semester 4) Project-V, Innovative activities-IV (Both in Semester 5) Project-VI, Innovative activities-V (Both in Semester 6) Project-VII, Innovative activities-VI (Both in Semester 7), Project-VIII (Semester 8)
8.	MC (8)	Induction Program, NSS/Physical Activities/Meditation and Yoga/Photography/Nature Club (Semesters 1 and 2, respectively) Behavioral and Interpersonal Skills, Constitution of India (Semesters 3 and 4, respectively) Environmental Science, Technical Lecture Presentation, and Group Discussion-I (Semesters 5 and 6, respectively) Social Awareness, Essence of Indian Knowledge Tradition (Semesters 7 and 8, respectively)

dissatisfaction. The general consensus is that there is little disagreement and an elevated level of agreement.

B.Tech. curriculum for CSE under regulation 21 (R21)

Modifications of Semesters 1 and 2 compared to R18 with relevance (see Table 6)

1. Basic Electronics (Theory and Practical) and Engineering Mechanics (Theory) have been excluded from second semester as students were exposed to the necessary fundamental knowledge's in their 12th standard extended Physics syllabus.
2. Here it must be mentioned that engineering graphics and workshop/manufacturing practice laboratories are kept intact from R18, as sufficient exposure of engineering drawing and hands-on training for mechanical workshops is the necessity for any engineering professional, irrespective of the discipline.
3. Professional Communication with Lab in first and second semester, respectively, is included with new content required for workplace communication.
4. In Mathematics II, basics of numerical methods is included. It is the prerequisite for Computer Engineering students for writing the program algorithms to analyze learner's computational thinking

TABLE 3 | Collected curriculum feedback for R18 from the stakeholders.

Stakeholder	Query 1 The curriculum was aligned with departmental mission of teaching-learning	Query 2 Employability was given importance in curriculum design and updated from time to time.	Query 3 The curriculum was well organized and options for choosing electives were adequate	Query 4 The curriculum allowed multidisciplinary growth of the students and satisfied all stakeholder's need	Query 5 The curriculum focused on design methodology, research and innovation.
Faculty and staff	20	20	20	20	20
Strongly agree	16	13	15	16	12
Moderately agree	4	5	5	3	5
Disagree	0	2	0	1	3
Students	70	70	70	70	70
Strongly agree	51	48	53	50	47
Moderately agree	16	15	12	16	16
Disagree	3	7	5	4	7
Alumni	40	40	40	40	40
Strongly agree	29	25	30	31	27
Moderately agree	9	10	8	6	8
Disagree	2	5	2	3	5
Industry	10	10	10	10	10
Strongly agree	7	6	8	7	6
Moderately agree	1	2	1	1	3
Disagree	2	2	1	2	1
Employer	10	10	10	10	10
Strongly agree	8	7	8	7	9
Moderately agree	1	2	1	2	1
Disagree	1	1	1	1	0

TABLE 4 | Overall feedback analysis considering all stakeholders.

Stakeholders (150)	Strongly agree	Moderately agree	Disagree	Remark
Query 1	111 (74%)	31 (20.6%)	8 (5.3%)	Feedback is good
Query 2	99 (66%)	34 (22.66%)	17 (11.33%)	Feedback is moderate, query-related curriculum portion may be reviewed
Query 3	114 (76%)	27 (18%)	9 (6%)	Feedback is good
Query 4	111 (74%)	28 (18.66%)	11 (7.3%)	Feedback is moderately good, but a review may be done
Query 5	101 (67.33%)	33 (32.67%)	16 (10.66%)	Feedback is moderate, query-related curriculum portion may be reviewed

which ultimately can be used to model any real-world problem's solution accurately (Belmar, 2022) (6).

Modifications of Semesters 3 and 4 compared to R18 with relevance (see Table 7)

1. Discrete Mathematics is newly included in third semester as it represents the Mathematics of computing to provide the knowledge of Mathematical thinking with corresponding logic; even if it does not vary smoothly, the trees, the graphs, and so is a prerequisite for learning algorithm and to enhance

the students' problem-solving skills by increasing the clarity of the solutions.

2. Analog electronics is another new inclusion in third semester CSE curriculum. In computers, software does not exist without any hardware, and computer engineers normally work in embedded systems where software interfaces with the hard electronics. So for working with audio or power monitoring or controls, computer engineers need a certain level of expertise to understand the analog electronics, which ultimately are converted into digital ones for subsequent storage and processing.
3. IT Workshop (Scilab/MATLAB/C++) theory is introduced in third semester to prepare the CSE students before engaging them in the corresponding

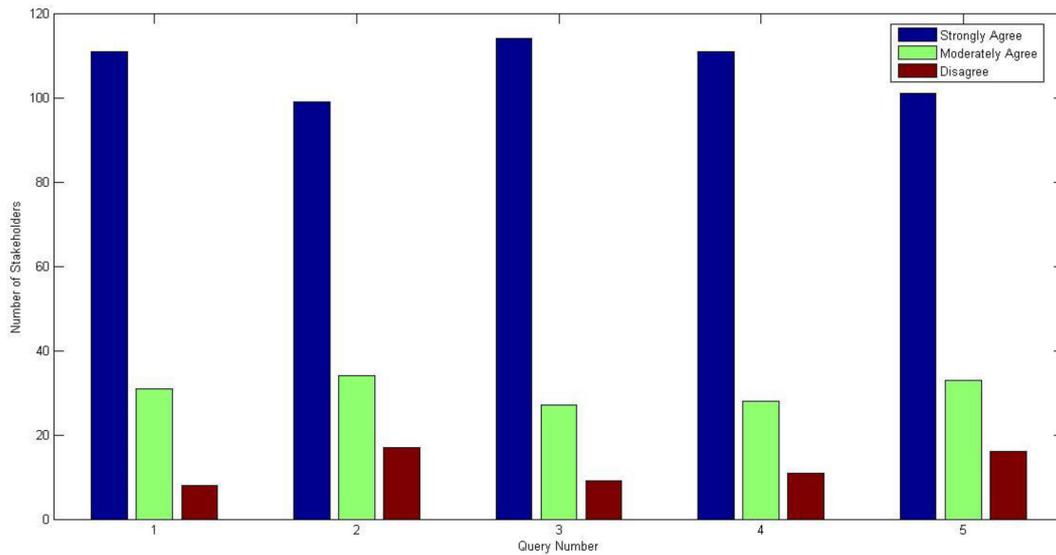


FIGURE 1 | Bar graph for stakeholders feedback.

TABLE 5 | UG CSE course structure under R18 and R21 as per the guideline of AICTE.

Sl. no.	Category	Credit allocation as per AICTE (R18)	Credit allocation as per autonomy (R18)	Credit allocation as per AICTE and autonomy (R21)
1	HSMC	12*	9	16
2	BSC	25*	25.5	23
3	ESC	24*	26	29
4	PCC	48*	50.5	59
5	PEC	18*	19.5	12
6	OEC	18*	15	9
7	PR	15*	14.5	15
8	MC	Non-credited	Non-credited	Non-credited
	Total	160	160	163

*Minor Variation is allowed by AICTE as per need of the respective disciplines.

lab. Actually, Scientific Laboratory (Scilab) is an open-source software unlike MATLAB, which is also used for data analysis and computation and so an alternative option for MATLAB to resolves the problem related to numeric data. From Scilab, students learn Scientific Computing (4, 7, 8).

- Probability and Statistics is introduced in fourth semester of the new curriculum as an essential subject. The integration of this subject here can create a wealth of new opportunities for professionals in the areas of data science, machine learning, and AI. So it plays a crucial role in developing and implementing any data-driven technology by providing the mathematical foundations needed to design, analyze, and evaluate computational systems by developing efficient algorithms to make informed decisions (Haleem et al. (7)).
- Programming using Python Lab is included in fourth semester as Python, being a very high-level computer programming language, is very easy to learn. It

is free and open-sourced with an available robust standard library and is commonly used to build websites and software, automate tasks, and conduct data analysis. Python is a general-purpose language, but its application is there in AI and Machine Learning. At present, most automation companies are using the Python language for coding the automation.

Here no major changes from the existing fifth semester curriculum were considered. In the sixth semester, a newly introduced open elective course (any one) is to be opted from either of the Bioinformatics or Internet of Things (IoT) or Robotics from the following consideration.

- Bioinformatics, a recent addition to the sixth-semester curriculum due to its interdisciplinary nature, demands collaboration between computer scientists and biologists. It involves utilizing computer technology to manage and analyze biological data. On the other hand, biological computation is a subset of computer engineering and computer science that

TABLE 6 | Semesters 1 and 2 curriculum for B.Tech. CSE (5).

Semester 1			Semester 2		
Category with code	Course name	Credit	Category with code	Course name	Credit
HSMC101	Professional Communication	2	HSMC291	Professional Communication Lab	1
BSC-PH101 and BSC-PH191	Physics-I (Semi-conductor Physics with Lab)	4.5	BSC-CH201 and BSC-CH291	Chemistry-I with Lab	4.5
BSC-M101	Mathematics-I (Vector Space, Differential Calculus)	4	BSC-M201	Mathematics-II (Numerical Methods, Differential Equation and Laplace Transformation)	4
ESC-ME191	Workshop/Manufacturing Practices	1.5	ESC-ME291	Engineering Graphics and Design	1.5
ESC-EE101 and ESC-EE191	Basic Electrical Engineering with Lab	4.5	ESC-CS201 and ESC-CS291	Programming for Problem Solving with Lab	4.5
Project PR191	Theme-based Project I	0.5	Project PR291	Theme-based Project II	0.5
Project PR192	Skill Development I	0.5	Project PR292	Skill Development II	0.5
	Total Credit (without MC)*	17.5		Total Credit	16.5

*MC: NSS/Physical Activities/Meditation and Yoga/Photography 3 Units.

TABLE 7 | Semesters 3 and 4 curriculum for CSE (5).

Semester 3			Semester 4		
Category	Course name	Credit	Category	Course name	Credit
BSC-M302	Discrete Mathematics	3	PCC-CS401 and CS491	Computer Organization and Architecture with Lab	4.5
ESC301	Analog Electronics	3	PCC-CS402 and CS492	Design and Analysis of Algorithms with Lab	4.5
PCC-CS302 and PCC-CS392	Data Structure with Lab	4.5	PCC-CS403 and CS493	Operating Systems with Lab	4.5
PCC-CS301 and PCC-CS391	IT Workshop – (Sci Lab/MATLAB) with Lab	4.5	PCC-CS404	Formal Language and Automata Theory	3
ESC302 and ESC392	Digital Logic and Electronics with Lab	4.5	HSMC402	Gender Culture and Development	2
HSMC303	Universal Human Values-II: Understanding Harmony and Ethical Human Conduct	3	BSC M(CSE)401	Probability and Statistics	3
BSC M(CS)391	Numerical Methods Lab	2.5	ESC491	Programming using Python	1.5
Project PR391	Theme-based Project III	0.5	Project PR491	Theme-based Project IV	0.5
Project PR392	Skill Development III (Technical Seminar Presentation)	0.5	Project PR492	Skill Development IV (Soft Skill and Aptitude-I)	0.5
HM301	MOOC Course I	4	HM401	MOOC Course II	4
	Total (with MOOCs) (without MC)*	30		Total (with MOOCs)	28

*MC: Environmental Science (Semester 3).

TABLE 8 | Semesters 5 and 6 curriculum for CSE (5).

Semester 5			Semester 6		
Category	Course name	Credit	Category	Course name	Credit
HSMC505	Principles of Management	2	HSMC604	Economics for Engineers	2
PCC-CS501 and PCC-CS591	Compiler Design with Lab	4.5	PCC-CS601	Computer Networks with Lab	4.5
PCC-CS502 and PCC-CS592	Database Management Systems with Lab	4.5	PCC-CS602	Software Engineering with Lab	4.5
PCC-CS503 and PCC-CS593	Object Oriented Programming using Java with Lab	4.5	PEC-CS-T-601	Microprocessor and Microcontroller with Lab	4.5
			PEC-CS-S-601	Advanced Operating Systems with Lab	
			PEC-CS-D-601	Machine Learning with Lab	
PEC-CS-T-501 and PEC-CS-T-591	Advanced Algorithms with Lab	4.5	PEC-CS-T-602	Parallel and Distributed Algorithms	3
			PEC-CS-S-602	Embedded Systems	
			PEC-CS-D-602	Soft Computing	
Project PR591	Minor Project I	1	OEC-CS-601A	Introduction to IoT	3
			OEC-CS-601B	Bio-informatics	
			OEC-CS-601C	Robotics	
Project PR592	Skill Development (Soft Skill and Aptitude-II)	0.5	Project PR691	Minor Project II	1
			Project PR692	Skill Development VI (Soft Skill and Aptitude-III)	0.5
HM501	MOOC Course III	4	HM601	MOOC Course IV	4
	Total with MOOCs (without MC)*	25.5		Total with MOOCs	27

*MC: Constitution of India (Semester 5).

- exploits biological principles to develop biological computers. Additionally, it employs computers to gain deeper insights into biology and address questions related to effectively storing, annotating, searching, and comparing biological data obtained from measurements and observations.
- The inclusion of the IoT (7, 8) in the sixth-semester syllabus is a response to the remarkable expansion of this transformative technology. The IoT's rapid growth is giving new shape to the world of technology. People can now explore creative ideas and produce new goods from the convenience of their homes thanks to the declining costs of standard IoT components. This course will facilitate the learners with a wide variety of applications in the IoT domain. Learners will acquire hands-on knowledge and real-world skills in wireless communication networks and IT. A methodical learning procedure of IoT will enable the learners to innovate IoT solutions in various fields.
 - To empower the learners to leverage IoT solutions, integration with Robotics as an open elective in the sixth semester will prove to be beneficial in this age of ultra-automation and AI-based systems and processes. The learners will also be able to acquire a solid foundation on fundamental topics like mathematical reasoning, circuit designing, programming, and physics. With this foundation, students can explore the field of creating sophisticated robotic solutions for dealing with challenges in the actual world.
 - With a strong emphasis on AI, machine learning is an alternative for a professional elective choice that has just been added to the sixth-semester curriculum. With the use of this course, software programs can produce accurate results without the need for explicit programming, such as outcome prediction. Rather, it makes more accurate choices and executes better by using historical data. Students who complete this course will have a stronger knowledge of machine

TABLE 9 | Semesters 7 and 8 curriculum for CSE (5).

Semester 7			Semester 8		
Category	Course name	Credit	Category	Course name	Credit
PEC-CS-T-701	Information Theory and Coding with Lab	4.5	PEC-CS-T-801	Advance Graph Algorithms	3
PEC-CS-S-701	Ad-Hoc and Sensor Networks with Lab		PEC-CS-S-801	Real-Time System	
PEC-CS-D-701	Data Mining and Data Warehouse with Lab		PEC-CS-D-801	Data Analytics	
PEC-CS-A-701	Cloud Computing with Lab		PEC-CS-A-801	Computer Graphics	
PEC-CS-T-702	Quantum Computing	3	OEC-CS-801A	Human Resource Development and Organizational Behavior	3
PEC-CS-S-702	Mobile Computing		OEC-CS-801B	VLSI	
PEC-CS-D-702	Natural Language Processing		OEC-CS-801C	Simulation and Modeling	
PEC-CS-A-702	Cryptography and Network Security				
OEC-CS-701A	High Performance Computing with Lab	4.5	OEC-CS-802A	Values and Ethics in Profession	3
OEC-CS-701B	Image Processing with Lab		OEC-CS-802B	History of Science	
OEC-CS-701C	Optimization Techniques with Lab		OEC-CS-802C	Economic Policies in India	
OEC-CS-702A	Cyber Law and Ethics	3			
OEC-CS-702B	Soft Skills and Interpersonal Communication				
OEC-CS-702C	Foreign Language				
PR791	Major Project-I	2	PR891	Major Project	6
PR792	Industrial Training/Internship	1	PR892	Grand Viva	1
PR793	Skill Development VII: Seminar and Group Discussion	0.5			
HM701	MOOCs Course-V	4	-	-	-
	Total with MOOCs (without MC)*	22.5			16

*MC: Entrepreneurship and Innovation Skill (Semester 7).

learning and be able to use data-driven methods to tackle difficult issues and reach intelligent decisions.

Modifications of Semesters 7 and 8 compared to R18 with relevance (Table 9)

1. High Performance Computing (HPC) in Open Elective 1 under seventh semester is a newly included course in R21 CSE curriculum, as it solves large, complex problems in far less time and at less cost than traditional computing. It is an emerging subject in the R21 CSE curriculum due to its ability to efficiently and cost-effectively tackle complex challenges, surpassing the capabilities of traditional computing methods (4).
2. Foreign language in the same semester is another significant addition of the R21 CSE curriculum (10–14), as it plays a crucial role in enhancing understanding and facilitating communication with a diverse range of individuals. Proficiency in a foreign language equips engineers with valuable skills to contribute effectively in the global economy.
3. In response to the widespread practical applications of graph algorithms across various industries, Advanced Graph Algorithm (as PEC) is newly included in eight semester of R21 CSE curriculum. These algorithms have proven instrumental in enabling social media companies to gain deeper insights into user interactions and relationships. Additionally, they have facilitated enhancements in logistics and transportation systems while aiding financial

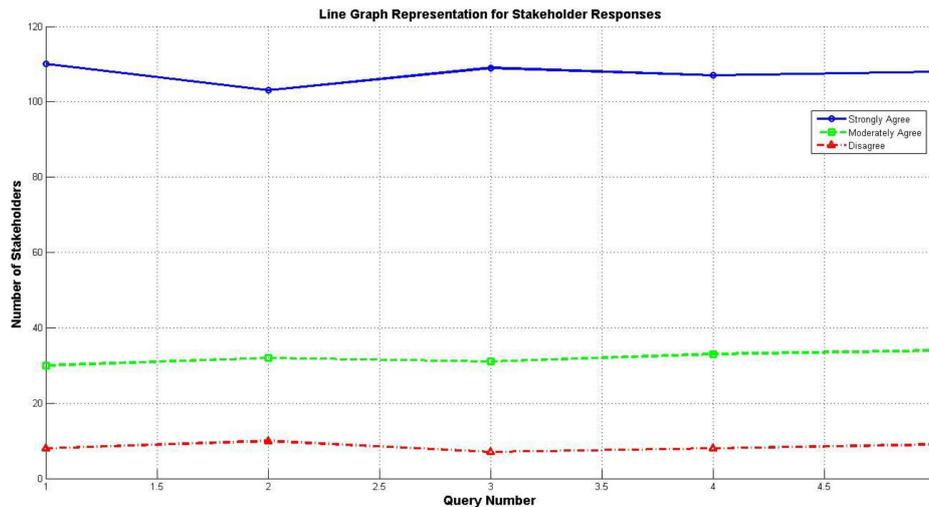


FIGURE 2 | Line graph representation for stakeholder responses.

institutions efficiently and swiftly for detecting instances of fraud.

- As part of the eight semester in the R21 CSE curriculum, a history of science course has been offered as one option for the OEC 2 to provide students with insights into the continuous nature of research and discovery. This course emphasizes that the principles and equations used by scientists to address problems have often emerged through extended and somewhat challenging processes.

So the total credit points allocated in eight semesters under R21 curriculum is 163 (from regular categories) and 20 (from MOOCs), with a total of 183.

Future Trends of Computer Engineering Education

Many prominent software sector executives suggest incorporating subjects like robotics, AI, and data analytics into the computer science curriculum. These areas of expertise are already in high demand, and a few colleges, including the institute under consideration, are offering these specialized courses after a job sector survey. Several other trends contribute to the exciting future of computer science. With an estimated global sphere to grow to 16 zettabytes by 2025, there will be huge requirements of data storage facilities. This will create fantastic opportunities for experts who can develop innovative solutions on data retention and storage, designing effective applications on cloud computing for anytime, anywhere access to businesses and individuals, data security, data optimization, and many more. AI has already revolutionized business and technology processes and is here to infinitely grow to make solutions for complex problems and repetitive tasks. Professionals with

development and implementation experience in AI will be in high demand as the technology becomes more widespread. In the era of digitalization, information security is crucial.

With the rise in cyber threats, protecting sensitive data and systems has become paramount for organizations. The field of computer science offers opportunities for individuals to specialize in information security and develop innovative solutions to safeguard digital assets. Here it may be mentioned that under India's National Education Policy (NEP) 2020, Regulation 23 (R23) is already taken up by AICTE (1) approved institutes to restructure and map certain aspects of the ongoing curriculum of R21 by broadly categorizing the entire course structure. The distribution highlights major (core), minor, interdisciplinary, ability enhancement courses, skill enhancement courses, value-added courses, summer internships, and research project/dissertations relevant to the Computer Science and Engineering curriculum with an aim to convert the country's computer science graduates to readily skilled workforces for handling effectively the rapid growth in this field as per the global standard.

Conclusion

This article presents a qualitative study on 4-year undergraduate B.Tech. CSE curriculum development. For choosing this research methodology, the background of this study is outlined. The findings may infer the fact that a proper curriculum or module design (Sloan et al. (10), Moller et al. (11), Sucharita et al. (12)) needs considerations from various perspectives related to the successful teaching and learning. These include a curriculum developer's or program administrator's capability of predicting the issues and shortcomings of existing curriculum, which not only should be rooted in a collegial context but it must fulfill the requirement of the professional world as well. In this

context, the global scenario comes into the surface where global recruiters like Amazon, Deloitte, CGI, Mindtree, HCL, Google, IBM, and Microsoft's requirements need to be addressed. But to incorporate the emerging areas with evolving content, the curriculum revision and redistribution for a subject like CSE should be done by incorporating the expected changes for the coming decades at least, as regular infrastructural modifications as per the requirement of the modified curriculum for an academic organization may not be an easy task, particularly for the self-financed ones.

Author contributions

The manuscript's conception, methodology, analysis, writing, and revision were all performed by both authors.

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