



LIFELONG SKILLS REQUIRED BY UNDERGRADUATE STUDENTS IN ELECTRICAL AND ELECTRONICS ENGINEERING EDUCATION FOR SUSTAINABLE DEVELOPMENT: A DESCRIPTIVE STUDY OF HIGHER EDUCATION IN INDIA

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Abstract

Rapid technological change, the global transition toward renewable and smart energy systems, and the expanding scope of the Sustainable Development Goals have placed new demands on undergraduate engineering education, requiring graduates to possess not only technical competence but also durable, transferable lifelong skills. This study examined the lifelong skills required by undergraduate students of Electrical and Electronics Engineering for sustainable development at Dr. Babasaheb Ambedkar Marathwada University (BAMU), Aurangabad, India. Grounded in lifelong learning theory (Knowles, 1975; Delors, 1996; Longworth, 2003) and the engineering-education-for-sustainable-development literature (Azapagic et al., 2005; Mulder, 2006; Segalàs et al., 2010), the study adopted a descriptive quantitative survey design administered to 150 final-year and pre-final-year Electrical and Electronics Engineering undergraduates. Data were collected using a structured, Likert-scaled questionnaire and analyzed using frequency counts, percentages, means, and standard deviations. Results showed that students rated self-directed learning, problem-solving and critical thinking, and digital and data literacy as the most needed lifelong skills for sustainable development (overall $M = 4.18$, $SD = 0.51$), while they rated the current curriculum's development of these skills as only moderate (overall $M = 2.89$, $SD = 0.62$), revealing a substantial gap between perceived need and perceived curricular provision. Environmental and sustainability literacy and systems thinking showed the widest gap between need and provision. The most frequently cited challenges were an examination-driven curriculum with limited project-based learning, insufficient industry exposure, and limited faculty training in sustainability-integrated pedagogy. The findings indicate that closing the lifelong-skills gap at BAMU requires deliberate curricular redesign, expanded project- and industry-based learning, and faculty development rather than the addition of stand-alone content modules alone. Five recommendations are offered for curriculum planners, faculty, and institutional leadership.

Keywords: lifelong, Development, Engineering, Education, Undergraduate

Introduction

The global engineering profession is undergoing sustained transformation driven by the transition to renewable energy, the electrification of transport, the growth of smart grids and the Internet of Things, and the increasingly explicit requirement that engineering solutions account for environmental, social, and



economic sustainability (United Nations, 2015; World Economic Forum, 2020). For Electrical and Electronics Engineering graduates, whose work underlies renewable power generation, energy-efficient systems, and digital infrastructure, technical competence alone is no longer regarded as sufficient. Professional bodies and accreditation frameworks have progressively broadened graduate attribute requirements to include lifelong learning capacity, systems thinking, teamwork, ethical responsibility, and sustainability literacy alongside discipline-specific knowledge (ABET, 2020; National Academy of Engineering, 2004).

Lifelong learning, understood as the capacity to continue learning independently and adaptively across a working life rather than relying solely on knowledge acquired during formal study, has long been recognized as central to engineering practice given the pace at which technology and regulation change after graduation (Knowles, 1975; Delors, 1996; Longworth, 2003). This recognition carries additional urgency in the context of sustainable development, since sustainability-related technical solutions and regulatory frameworks continue to evolve rapidly, requiring practicing engineers to update their competence well beyond what any undergraduate curriculum can anticipate at graduation (Mulder, 2006; Wals, 2014).

Within the Indian higher education context, undergraduate engineering curricula, including Electrical and Electronics Engineering, have historically emphasized technical and theoretical content aligned with examination performance, with comparatively limited structured attention to lifelong learning skills, sustainability literacy, and other transferable competencies (AICTE, 2018). Dr. Babasaheb Ambedkar Marathwada University (BAMU), Aurangabad, a leading state university in the Marathwada region of Maharashtra, India, offers undergraduate programs in Electrical and Electronics Engineering through its affiliated colleges and, like many Indian technical institutions, has begun incorporating outcome-based education and graduate attribute frameworks in response to national accreditation requirements (AICTE, 2018). Whether students themselves perceive these efforts as adequately developing the lifelong skills they judge necessary for a career oriented toward sustainable development has not, however, been systematically documented. This study addresses that gap by surveying undergraduate Electrical and Electronics Engineering students at BAMU on their perceptions of required lifelong skills, the extent to which their curriculum develops those skills, and the challenges they associate with that development.

Statement of the Problem

Engineering education researchers have argued that a persistent gap exists between the lifelong and sustainability-related skills that engineering graduates are expected to bring to the workplace and the skills that conventional, content-heavy undergraduate curricula actually develop (Azapagic et al., 2005; Fenner et al., 2005; Segalàs et al., 2010). Without descriptive evidence of how this gap is perceived by students themselves within a specific institutional context, curriculum planners at institutions such as BAMU risk



relying on generic, internationally derived assumptions about graduate attributes rather than on a locally grounded understanding of where the gap is widest and what obstacles most impede its closure. This study was designed to supply that locally grounded descriptive evidence.

Objectives of the Study

The study pursued four objectives:

1. To determine the demographic profile of the undergraduate Electrical and Electronics Engineering students surveyed.
2. To determine students' perceived level of need for specific lifelong skills for sustainable development.
3. To determine the extent to which students perceive their current curriculum as developing those lifelong skills.
4. To identify the challenges students associate with the development of lifelong skills for sustainable development within their program.

Significance of the Study

The findings are intended to benefit curriculum planners and academic council members at BAMU and similarly situated Indian technical institutions by identifying which lifelong skills show the widest gap between perceived need and perceived curricular provision, and therefore where curricular redesign should be prioritized. Faculty members stand to benefit from evidence on which pedagogical and institutional obstacles students themselves identify as most significant. Finally, the study contributes to the broader literature on engineering education for sustainable development by providing descriptive data from an Indian regional university context that is underrepresented relative to the European and North American contexts from which much of the existing literature is drawn (Azapagic et al., 2005; Mulder, 2006).

Lifelong Learning: Concept and Rationale

Lifelong learning has been defined as a self-initiated, continuous process of acquiring knowledge, skills, and dispositions across the lifespan, extending well beyond the boundaries of formal schooling (Knowles, 1975). UNESCO's influential formulation of lifelong learning organized the concept around four pillars, learning to know, learning to do, learning to live together, and learning to be, each of which was framed as a foundation for adaptive, self-directed engagement with a changing world (Delors, 1996). Longworth (2003) extended this framework specifically to institutional practice, arguing that educational institutions bear responsibility for cultivating the disposition and skill set for continued learning, rather than treating a fixed body of content as a terminal outcome of formal education. For engineering education specifically, lifelong learning capacity has been identified as a core graduate attribute precisely because engineering knowledge, standards, and technologies change at a pace that renders any fixed undergraduate curriculum incomplete within a few years of graduation (National Academy of Engineering, 2004; ABET, 2020).



Sustainable Development and Engineering Education

The 2030 Agenda for Sustainable Development, adopted by the United Nations (2015), establishes seventeen interconnected goals spanning environmental, social, and economic dimensions of development, several of which, including affordable and clean energy, industry and infrastructure, and climate action, bear directly on the work of electrical and electronics engineers. Engineering education researchers have argued that preparing engineers to contribute to these goals requires curricula that go beyond technical content to include systems thinking, an understanding of the environmental and social consequences of engineering decisions, and the capacity to work across disciplinary and stakeholder boundaries (Fenner et al., 2005; Sterling, 2004). Azapagic *et al.* (2005), in a widely cited European survey, found that engineering students, while generally supportive of sustainable development as a concept, reported limited understanding of how to apply sustainability principles within their own technical discipline, a finding echoed in subsequent research on the gap between stated curricular commitment to sustainability and its actual integration into technical coursework (Segalàs *et al.*, 2010; Mulder, 2006). Wals (2014) further argued that institutionalizing sustainability in higher education requires sustained systemic change, including changes to pedagogy, assessment, and faculty capacity, rather than the addition of isolated sustainability-themed elective courses.

Lifelong Skills for Electrical and Electronics Engineering Graduates

Building on the general engineering-education-for-sustainable-development literature, several skill domains recur as particularly relevant to Electrical and Electronics Engineering graduates working toward sustainable development outcomes. Self-directed and continuous learning capacity is required given the pace of change in power electronics, renewable energy technology, and digital systems (Knowles, 1975; National Academy of Engineering, 2004). Problem-solving and critical thinking are required to evaluate trade-offs among competing technical, economic, and environmental constraints in areas such as renewable energy integration and grid design (Trilling & Fadel, 2009). Digital and data literacy, including familiarity with simulation, modeling, and data-driven decision tools, has become a baseline expectation as digitalization accelerates (World Economic Forum, 2020). Systems thinking, the capacity to understand a technical component as part of a larger interconnected environmental, economic, and social system, is repeatedly identified as central to sustainability-oriented engineering practice (Fenner et al., 2005; Sterling, 2004). Environmental and sustainability literacy, encompassing understanding of environmental impact assessment and life-cycle thinking, is directly required by the sustainability mandate itself (Azapagic et al., 2005; Ramirez, 2012). Communication and teamwork are required for engineers to work across disciplinary and stakeholder boundaries on complex sustainability-oriented projects (Trilling & Fadel, 2009). Ethical and professional responsibility, encompassing awareness of the social and environmental consequences of engineering decisions, is embedded in most accreditation frameworks (ABET, 2020). Finally, adaptability and leadership are necessary for graduates entering a rapidly changing energy and technology sector (World Economic Forum, 2020).



Related Studies and the Indian Context

Within the Indian technical education system, the All India Council for Technical Education has progressively incorporated outcome-based education, graduate attributes, and employability-oriented skill requirements into its model curriculum guidelines for engineering programs, including explicit reference to lifelong learning and environmental sustainability as graduate attributes (AICTE, 2018). However, researchers examining engineering education for sustainable development have generally cautioned that formal inclusion of such attributes within official curriculum documents does not guarantee their actual development in the classroom, particularly where assessment remains oriented toward content recall rather than applied, project-based demonstration of skill (Segalàs et al., 2010; Mulder, 2006). This tension between stated curricular intent and classroom reality provides the immediate motivation for the present descriptive study.

Methodology

The study employed a descriptive quantitative survey design, appropriate for characterizing a population's perceptions of skill need, curricular provision, and associated challenges without manipulating variables or testing a causal hypothesis (Creswell, 2014; Best & Kahn, 2006). A descriptive design was considered appropriate as a foundation for subsequent curriculum reform and intervention research, since it identifies where perceived gaps are widest and what obstacles are most salient prior to designing a specific intervention.

The population comprised undergraduate students enrolled in Electrical and Electronics Engineering programs affiliated with Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. A sample of 150 pre-final-year (third-year) and final-year (fourth-year) students was selected using stratified random sampling across three affiliated engineering colleges, with strata defined by year of study, to ensure that respondents had sufficient exposure to the curriculum to evaluate its skill-development provisions. Table 1 presents the demographic profile of the sample.

Table 1 Demographic Profile of Respondents (N = 150)

Variable	Category	Frequency	(%)
Sex	Male	98	65.3
	Female	52	34.7
Year of study	Third year	79	52.7
	Final year	71	47.3
Age	19–20 years	61	40.7
	21–22 years	74	49.3
	Above 22 years	15	10.0
Prior internship or industry exposure	Yes	64	42.7
	No	86	57.3



Variable	Category	Frequency	(%)
Prior exposure to renewable energy or sustainability coursework	Yes	58	38.7
	No	92	61.3

As Table 1 shows, the sample was predominantly male (65.3%), fairly evenly split between third-year (52.7%) and final-year (47.3%) students, and predominantly aged 21–22 years (49.3%). A majority of respondents (57.3%) reported no prior internship or structured industry exposure, and a majority (61.3%) reported no prior exposure to dedicated renewable energy or sustainability coursework, both figures relevant to the interpretation of the curricular-provision findings reported in Section 4.

Instrument

Data were collected using a structured questionnaire developed by the researcher on the basis of the lifelong-skill domains identified in Section 2.3. The questionnaire comprised four sections: Section A collected demographic information; Section B measured students' perceived level of need for ten lifelong skill domains using a five-point Likert scale (1 = not needed to 5 = essential; Likert, 1932); Section C measured students' perceived extent of curricular provision for the same ten skill domains using a five-point Likert scale (1 = not at all developed to 5 = extensively developed); and Section D listed eight commonly cited implementation challenges, which respondents ranked by frequency of occurrence in their own program. Mean scores on the five-point scales were interpreted using the following descriptive rating: 4.21–5.00 (very high), 3.41–4.20 (high), 2.61–3.40 (moderate), 1.81–2.60 (low), and 1.00–1.80 (very low).

Validity and Reliability

Content validity was established through review by three engineering education faculty members who evaluated each item for clarity and alignment with the skill domains defined in Section 2.3, following which items were revised. A pilot test was conducted with 25 students who did not participate in the main study, and internal consistency reliability was calculated using Cronbach's alpha (Taber, 2018). The skill-need subscale returned a coefficient of .86 and the curricular-provision subscale returned a coefficient of .83, both exceeding the conventionally accepted threshold of .70 for research instruments (Cohen *et al.*, 2018).

Data Collection Procedure

The questionnaire was administered in both paper and electronic form across the three sampled colleges over a three-week period, with the assistance of departmental coordinators. Participation was voluntary and anonymous. Of 175 questionnaires distributed, 150 were returned complete and usable, yielding a response rate of 85.7 percent.

Data Analysis

Demographic data were summarized using frequency counts and percentages. Responses to the skill-need and curricular-provision subscales were summarized using item-level and overall means and standard deviations, interpreted against the descriptive rating scale specified in Section 3.3, and compared



to identify the gap between perceived need and perceived provision for each skill domain. Challenge-ranking data were summarized using frequency counts and percentages, ordered from most to least frequently report.

Results

Research Question1: what are the Perceived Level of Need for Lifelong Skills. Table 2 presents students' perceived level of need for ten lifelong skill domains for sustainable development practice in Electrical and Electronics Engineering.

Table 2: Summary of the Perceived Level of Need for Lifelong Skills for Sustainable Development (n = 150)

Skill Domain	M	SD	Rank
Self-directed and continuous learning capacity	4.41	0.49	1
Problem-solving and critical thinking	4.38	0.52	2
Digital and data literacy (simulation, modeling, data tools)	4.33	0.55	3
Adaptability to changing technology and career pathways	4.29	0.57	4
Ethical and professional responsibility	4.24	0.58	5
Communication skills	4.19	0.60	6
Teamwork and collaboration across disciplines	4.11	0.63	7
Systems thinking	4.02	0.66	8
Environmental and sustainability literacy	3.96	0.68	9
Leadership and project management	3.87	0.70	10
Overall Mean	4.18	0.51	—

Table 2 showed the overall mean of 4.18 (SD = 0.51) indicates that students perceived lifelong skills for sustainable development as highly needed overall, approaching the “very high” band. Self-directed and continuous learning capacity was rated highest (M = 4.41), consistent with lifelong learning theory's emphasis on the learner's own disposition toward continued learning as foundational to all other skill development (Knowles, 1975; Longworth, 2003). Leadership and project management (M = 3.87) and environmental and sustainability literacy (M = 3.96) were rated lowest, though still within the “high” band, suggesting that students recognize these domains as less immediately central to their day-to-day technical training than problem-solving or digital literacy.

Research Question 2: what are the Perceived Extent of Curricular Provision

Table 3 presents students' perceived extent to which their current curriculum develops the same ten lifelong skill domains.

**Table 3 Perceived Extent of Curricular Provision for Lifelong Skills (n= 150)**

Skill Domain	M	SD	Rank
Problem-solving and critical thinking	3.54	0.64	1
Teamwork and collaboration across disciplines	3.28	0.69	2
Communication skills	3.19	0.71	3
Digital and data literacy (simulation, modeling, data tools)	3.11	0.73	4
Ethical and professional responsibility	2.94	0.75	5
Self-directed and continuous learning capacity	2.81	0.77	6
Adaptability to changing technology and career pathways	2.69	0.79	7
Leadership and project management	2.58	0.81	8
Systems thinking	2.44	0.83	9
Environmental and sustainability literacy	2.31	0.85	10
Overall Mean	2.89	0.62	—

Table 3 showed the overall mean of 2.89 (SD = 0.62) indicates that students perceived curricular provision for lifelong skills as only moderate, and notably lower than the high level of perceived need reported in Table 2. Problem-solving and critical thinking was the most consistently developed skill (M = 3.54), likely reflecting its long-standing embedding within core technical coursework and laboratory work. Environmental and sustainability literacy (M = 2.31) and systems thinking (M = 2.44) were the least developed domains, both falling toward the “low” end of the moderate band.

Research Question 3: What are the Comparison of Need and Provision

A direct comparison of Tables 2 and 3 shows a gap of 1.29 scale points between overall perceived need (M = 4.18) and overall perceived provision (M = 2.89). Table 4 presents the gap for each individual skill domain, ranked from widest to narrowest.



Table 4: summary of Gap between Perceived Need and Perceived Curricular Provision, by Skill Domain (N = 150)

Skill Domain	Need M	Provision M	Gap
Environmental and sustainability literacy	3.96	2.31	1.65
Systems thinking	4.02	2.44	1.58
Self-directed and continuous learning capacity	4.41	2.81	1.60
Adaptability to changing technology and career pathways	4.29	2.69	1.60
Leadership and project management	3.87	2.58	1.29
Ethical and professional responsibility	4.24	2.94	1.30
Digital and data literacy	4.33	3.11	1.22
Communication skills	4.19	3.19	1.00
Teamwork and collaboration across disciplines	4.11	3.28	0.83
Problem-solving and critical thinking	4.38	3.54	0.84

As Table 4 shows, the widest gaps were found for environmental and sustainability literacy (1.65), self-directed and continuous learning capacity (1.60), adaptability (1.60), and systems thinking (1.58), indicating that the skill domains most directly tied to sustainable development practice and to lifelong learning capacity itself are precisely the domains students perceive as least developed by their current program. The narrowest gaps were found for teamwork (0.83) and problem-solving (0.84), both of which are more conventionally embedded in existing laboratory and project coursework.

Research Question 4: What are the Challenges to Developing Lifelong Skills?

Table 5 presents the challenges students most frequently associated with the development of lifelong skills for sustainable development within their program.



Table 5 Challenges to Developing Lifelong Skills for Sustainable Development (N = 150)

S/No	Challenge	Frequency	(%)	Rank
1	Examination-driven curriculum with limited project-based assessment	121	80.7	1
2	Insufficient industry exposure or internship opportunities	108	72.0	2
3	Limited integration of sustainability content within core technical courses	98	65.3	3
4	Limited faculty training in sustainability-integrated or project-based pedagogy	87	58.0	4
5	Large class sizes limiting hands-on laboratory and project work	79	52.7	5
6	Outdated laboratory equipment relative to current industry technology	71	47.3	6
7	Limited access to digital simulation and modeling software	58	38.7	7
8	Limited awareness among students of relevant Sustainable Development Goals	49	32.7	8

Table 5 revealed that examination-driven curriculum design (80.7%) and insufficient industry exposure (72.0%) were the two most frequently cited challenges, together suggesting that assessment structure and limited applied, real-world engagement are the primary perceived obstacles to lifelong-skill development, ahead of resource constraints such as outdated equipment (47.3%) or limited software access (38.7%).

Discussion of Findings

The findings indicate that undergraduate Electrical and Electronics Engineering students at BAMU place high value on lifelong skills for sustainable development, with self-directed learning, problem-solving, and digital literacy rated as most essential, consistent with the broader lifelong learning and engineering education literature (Knowles, 1975; National Academy of Engineering, 2004; World Economic Forum, 2020). However, students perceive their current curriculum as providing only moderate



development of these skills, and the gap is widest precisely for the skill domains most closely tied to sustainability practice and lifelong learning capacity, namely environmental and sustainability literacy, systems thinking, self-directed learning, and adaptability. This pattern is consistent with prior findings that engineering curricula often retain strong technical content while under-developing the cross-cutting, transferable, and sustainability-specific competencies that accreditation frameworks increasingly require (Azapagic *et al.*, 2005; Segalàs *et al.*, 2010; Mulder, 2006).

The comparatively narrow gap for problem-solving and teamwork, both of which are already embedded in conventional laboratory and project coursework, suggests that BAMU's Electrical and Electronics Engineering programs are not failing to develop lifelong skills uniformly, but are developing skills unevenly, favoring domains that fit naturally within existing technical coursework over domains, such as sustainability literacy and self-directed learning, that require more deliberate curricular and pedagogical redesign (Wals, 2014; Sterling, 2004). The challenge data reinforce this interpretation: the most frequently cited obstacles, an examination-driven curriculum and insufficient industry exposure, point to structural and pedagogical features of the program rather than to a lack of student interest or a simple shortage of physical resources, since resource-related challenges such as outdated equipment and limited software access were ranked lower. This is consistent with Wals's (2014) argument that institutionalizing sustainability-related competence in higher education requires systemic pedagogical and assessment change rather than the addition of isolated content.

Recommendations

Based on the findings of this study, the following five recommendations are offered for curriculum planners, faculty, and institutional leadership at BAMU and similarly situated Indian technical universities.

1. Redesign assessment to reward applied, project-based demonstration of lifelong skills rather than content recall alone. Because an examination-driven curriculum was the most frequently cited obstacle, and because self-directed learning and adaptability showed among the widest need-provision gaps, academic councils should expand project-based and portfolio assessment components within core Electrical and Electronics Engineering courses, so that lifelong skills are assessed as directly as technical content
2. Integrate sustainability and systems-thinking content directly into core technical courses rather than isolated elective modules. Because environmental and sustainability literacy and systems thinking showed the widest need-provision gaps, curriculum committees should embed sustainability case studies, life-cycle thinking, and systems-level design exercises within core courses such as power systems, renewable energy conversion, and control systems, consistent with the argument that sustainability competence is best developed through integration rather than isolated coverage



3. Expand structured industry exposure and internship opportunities. Because insufficient industry exposure was the second most frequently cited obstacle, and given that only 42.7 percent of surveyed students reported prior internship experience, the university should formalize partnerships with regional power utilities, renewable energy firms, and electronics manufacturers to guarantee structured internship placements for all students prior to graduation.
4. Invest in faculty development focused on sustainability-integrated and project-based pedagogy. Because limited faculty training was the fourth most frequently cited obstacle, the university should provide structured professional development for faculty in designing and facilitating project-based, sustainability-integrated coursework, since curricular redesign alone is unlikely to succeed without corresponding faculty capacity
5. Strengthen self-directed and lifelong learning capacity through structured independent and collaborative project work. Because self-directed learning was rated the single most needed skill yet among the domains with the widest provision gap, faculty should incorporate structured opportunities for independent inquiry, such as open-ended design projects and self-paced online learning components, with scaffolded milestones and peer review, to build the self-directed learning capacity that lifelong learning theory identifies as foundational to continued professional development (Knowles, 1975; Longworth, 2003).

Conclusion

This descriptive study examined the lifelong skills undergraduate Electrical and Electronics Engineering students at BAMU perceive as necessary for sustainable development, the extent to which they perceive their current curriculum as developing those skills, and the challenges they associate with that development. These findings suggest that closing the lifelong-skills gap in Electrical and Electronics Engineering education at BAMU requires deliberate assessment reform, curricular integration of sustainability content, expanded industry exposure, and sustained faculty development, rather than the addition of isolated skill-building modules alone. Future research combining this descriptive survey approach with curriculum audit and employer feedback would help verify whether the skill domains students identify as under-developed correspond to the competencies employers in the regional renewable energy and electronics sector actually require.

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