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Title: **Survey of Linux-Based Free Software Tools for Electrical and Computer Engineering (ECE)**

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Survey of Linux-Based Free Software Tools for Electrical and Computer Engineering (ECE)

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ABSTRACT The undergraduate program in Electrical and Computer Engineering (ECE) is a four-year curriculum where students work on several software to complete their coursework. These tools are accessible to students in universities where they spend several hours completing their assignments, a process not doable under the COVID-19 global lockdown. Hence, students either (i) access their university labs remotely via virtual private networks, or in the absence of remote access (sadly) (ii) resort to using pirated software, or (regretfully) (iii) are deprived of hands-on knowledge of the course. In this (post) COVID-19 era, educators are required to adopt teaching pedagogy in order to ensure maximum delivery of their course material. In an attempt to facilitate experimental learning, this effort provides a detailed survey of Linux-based tools coupled with their corresponding coursework within ECE with the hope that the content provided in this paper would be of some relief to students and teachers engaged in ECE education globally.

INDEX TERMS Linux, circuit analysis, electronic design automation, mathematics, power engineering, programming

1. INTRODUCTION

COVID-19 pandemic resulted in the lock-down of academic institutions across the world. Over 1.2 billion students were unable to attend classrooms, giving rise to e-learning where teaching is undertaken remotely via digital platforms. COVID-19 pandemic highlighted the importance of e-inclusion in educational crisis. This gave rise to new opportunities, defining future education, development of ICT infrastructure, provision of digital devices, adequate learning resources, and support material for teachers and learners. Hence, universities adopted several software to facilitate their students through content distribution and improved visibility to analytical frameworks as well as improved communication channels.

Computer aided design (CAD) helps to understand key principles in a course by allowing the user to experience a simulated environment mimicking real life situations. Hence, if CAD solutions are affordable and free of cost, student learning may vastly improve in underprivileged communities and countries falling in low-income group.

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For improved e-learning, it is recommended that any course must make use of four modalities [1]:

- visuals (demonstrations using descriptions and pictures)
- auditory sensations (dialogues and discussions)
- tactile perceptions (labs and hands-on work)
- kinaesthetic impressions (movement)

Several online platforms, such as Khan Academy [2], MIT Open Courseware (MIT-OCW) [1]–[3], Udemy [4], Coursera [5], and edX [6] provide courses, online lectures, assignments, exams, and solutions on a broad range of topics. Universities have also started providing free online coursework. In terms of engineering education, the above-mentioned online courses provide engaging visual and auditory faculties. However, they are limited in engaging tactile perceptions and kinaesthetic impressions. This primarily affects engineering since its courses are often associated with lab work.

In fact, engineering labs often require resources and software packages that are generally expensive. Hence, students either (i) spend significant time in labs completing their work, an option that is not feasible under lock-down scenarios, or (ii) remotely access university's facilities via virtual private networks, an option usually available only in high-income countries; or (iii) pay for this expensive software themselves, an option that many cannot afford. Since most of the tools are expensive, many students end up with (iv) pirating software. Figures 1 and 2 provide a glimpse of the distribution of software piracy among five continents.

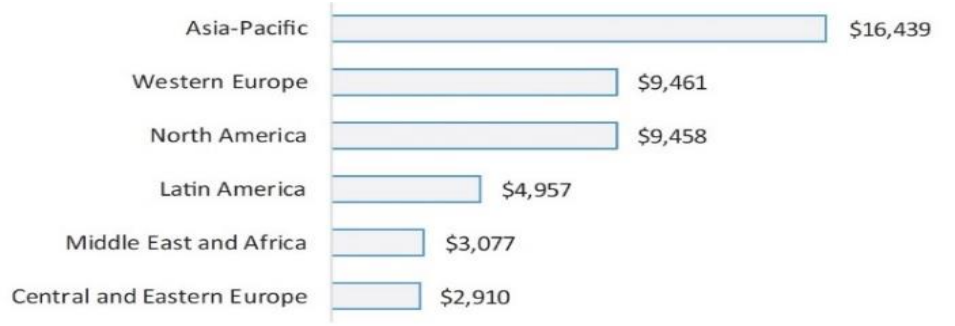

FIGURE 1. Commercial value of unlicensed software use (in Millions) [7]

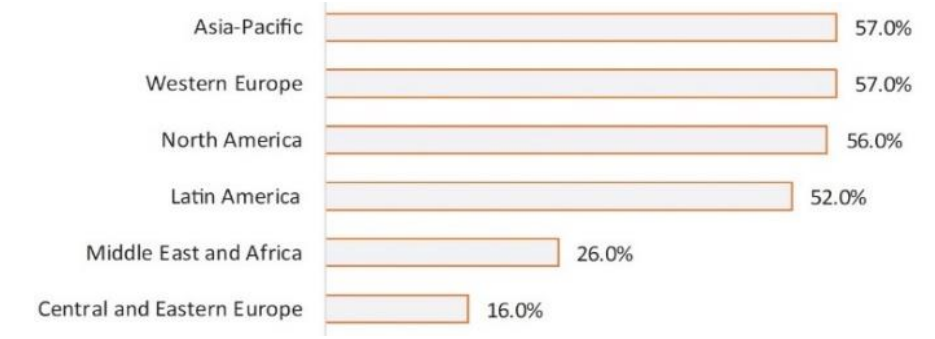

FIGURE 2. Average rate of unlicensed software [7]

Therefore, to facilitate Electrical and Computer Engineering (ECE) education, this effort promotes the use of Linux operating systems within ECE (Section-II). Moreover, it also provides an extensive survey of free CAD tools available for ECE coursework (Section-III) and concludes by suggesting future directions within the same (Section IV).

2. LINUX

Popular operating systems are Windows, Linux, and macOS. Among these three, Linux is a popular platform for developers, as shown in Figure 3.

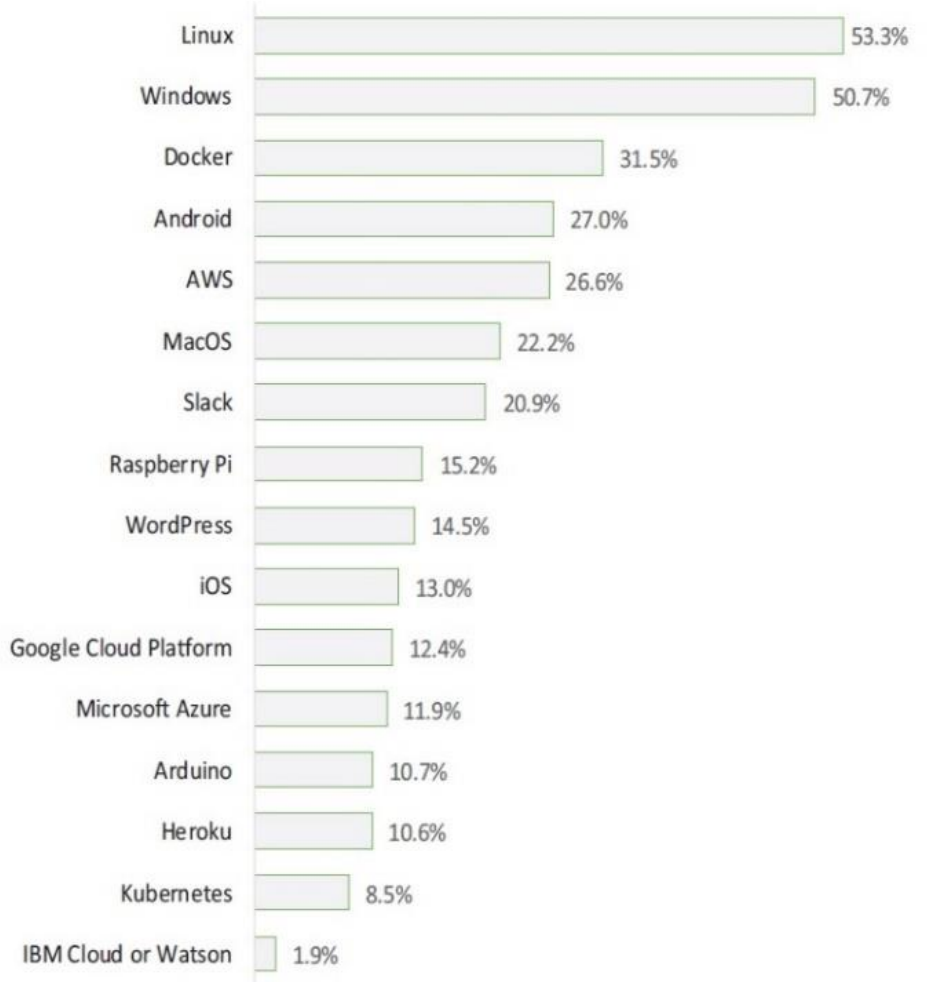

FIGURE 3. Survey conducted by stack overflow

Linux offers several advantages over Windows and macOS. Being an open-source, Linux provides unmatched flexibility and customizability. This allows users to modify and optimize it to their specific requirements, something Windows

and macOS do not permit. Furthermore, it also excels in cost-effectiveness, since it is free to use and distribute, unlike macOS, which is tied to expensive Apple hardware or Windows. Additionally, Linux is secure, as it has a robust architecture and strong community-driven updates, making it less prone to malware and cyberattacks. Moreover, Linux offers exceptional performance on a wide range of hardware, from supercomputers, servers to aging PCs. While macOS is restricted to Apple devices, and Windows often demand higher system resources. For developers and tech enthusiasts, Linux provides a rich ecosystem of tools and programming support that surpasses the capabilities of both macOS and Windows. This further solidifies its position as the operating system of choice for innovation and versatility [8]. Additionally, it is useful for students since it allows its users to sudo ('super user do') troubleshoot, customize, install, and upgrade their system, making them polish their computing skills.

Among Linux distributions, Google Trends highlight Ubuntu as the most popular distribution (see Figures 4 – 6). Whereas, Fedora tops the list in Alexa Traffic Statistics with openSUSE occupying the median among popular Linux distributions.

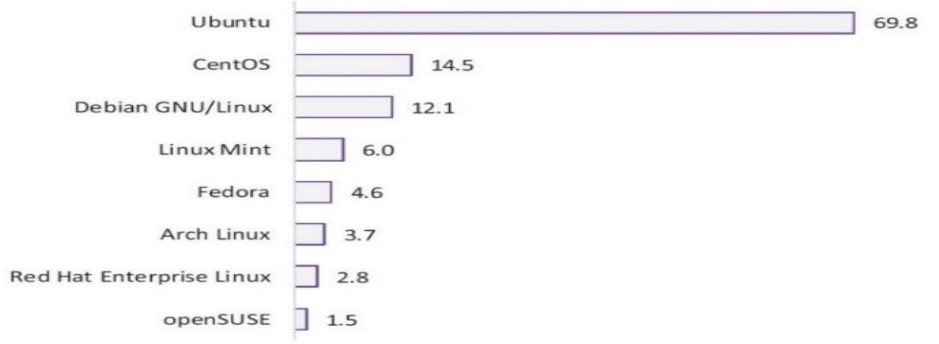

FIGURE 4. Google trends survey

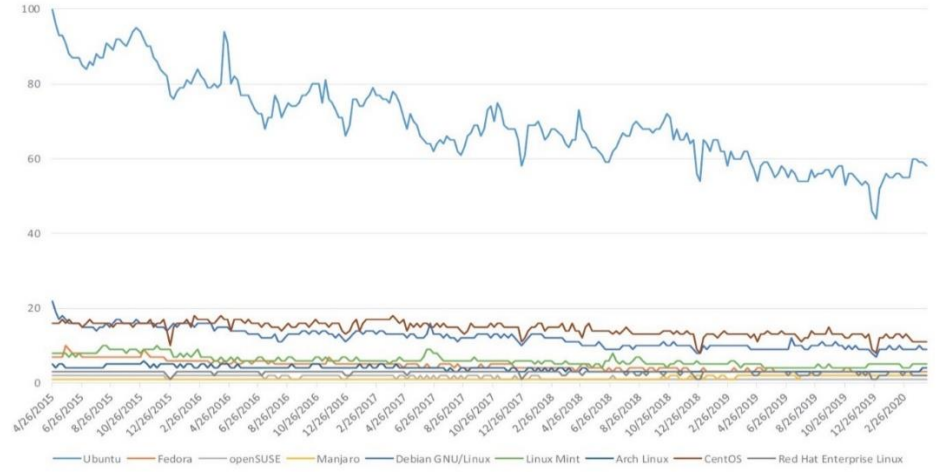

FIGURE 5. Google trends survey

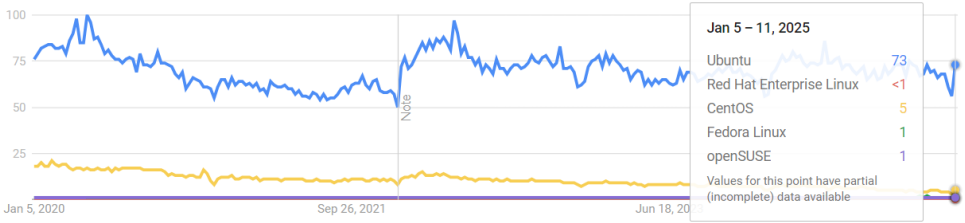

FIGURE 6. Google trends survey

Figure 3 shows platform usage among developers and students. As one can see, Linux is one of the most popular operating systems. Figure 4 shows the relative popularity of different Linux distributions among users. For instance, Ubuntu, openSUSE, and Fedora together make up 76% of Linux usage. Figure 5 shows the relative popularity of different Linux distributions among users. For instance, together Ubuntu, openSUSE, and Fedora make up 76% of Linux usage. Figure 6 shows that after the initial downward popularity of Ubuntu (2015 – 2020), the popularity of Ubuntu has remained steady in the last five years (2020 – 2025). Please note, CentOS's support was discontinued after Dec. 31st 2021.

A brief comparison of some Linux distributions is presented in Table I. Together, Ubuntu, Fedora, and OpenSUSE constitute 76% of the entire Linux community. Moreover, Ubuntu, Fedora, and openSUSE represent popular versions of the Debian, RedHat, and SUSE flavours of Linux.

TABLE I

COMPARISON OF SOME POPULAR FREE LINUX DISTRIBUTIONS SORTED WITH REFERENCE TO ALEXA BOUNCE RATES [8].

S. No.	Operating System	Current Stable Version	Support (End of Life)	Package Management System	Purpose	Alexa bounce rates
1	Fedora	Fedora 41 (Oct 29, 2024)	November 2025	RPM-based Yum, Snap, Flatpak, Appimage	General, Server, Desktop	64.00
2	Arch Linux	Rolling	Rolling	Pacman, Snap, Flatpak, Appimage	General	63.20
3	Red Hat Enterprise Linux	RHEL 9.5	May 2034	RPM	Server	59.80
4	Debian	Debian 12	June 2028	APT (Synaptic), Snap,	General, Server, Desktop	59.30

S. No.	Operating System	Current Stable Version	Support (End of Life)	Package Management System	Purpose	Alexa bounce rates
5	openSUSE	openSUSE Leap 15.5 (Jun 7, 2023)	December 2024	Flatpak, AppImage RPM-based Yast, Snap, Flatpak, Appimage	General, Desktop	57.50
6	CentOS	CentOS Linux (Discontinued)	Ended on Dec. 31, 2021	RPM, yum/up2date	Server	55.30
7	Linux Mint	Linux Mint 21.2	April 2027	APT (Synaptic), mintInstall, Snap, Flatpak, AppImage	General, Server, Desktop	53.90
8	Ubuntu	Ubuntu 24.04 LTS	April 2029	APT (Synaptic), Ubuntu Software Center, Snap, Flatpak, AppImage	General	47.20
9	Manjaro	Rolling	Rolling	Pacman, Snap	General	38.10

The following section (Section-III) provides an extensive survey of existing ECE-related CAD tools present in the Linux community.

3. LINUX SOFTWARE FOR ECE

To conduct a thorough survey, the authors categorized all ECE courses in seven broad categories (Table II). Here, each category is assigned a category code which helps relate corresponding courses in ECE to their respective categories, as shown in III. For the sake of brevity, each category has been assigned a code allowing corresponding ECE courses to relate to these categories, as shown in Table III.

Lastly, Table IV provides an extensive survey of related tools presented within the Linux ecosystem for each of the seven categories of courses. Together, Tables II, III, and IV make it easier for faculty and students to find and select appropriate tools for their respective ECE courses.

TABLE II

SEVEN BROAD SUBJECT CATEGORIES WHICH COLLECTIVELY CLASSIFY COURSES OFFERED IN AN UNDERGRADUATE ECE PROGRAM

No	ECE Category	Code
1	Mathematical and Numerical Analysis	MN
2	Programming	PROG
3	Circuit Analysis and PCB Design	CPCB
4	Power Systems	PS
5	Embedded Systems	EMBD
6	Communication Systems	COMM
7	Technical Writing and Presentation	TWP

TABLE III

LIST OF ALL COURSES OFFERED IN AN UNDERGRADUATE PROGRAM ALONG WITH THEIR SUGGESTED CATEGORIES

Yr.	ECE Curriculum Course	Category
Freshman	Electric Circuit Theory	CPCB
	Calculus	MN
	Differential Equations	MN
	Multivariate Calculus	MN
	Communication Skills	TWP
	Computer Fundamentals	PROG
Sophomore	Semiconductor Devices	CPCB
	Digital System Design	CPCB
	Analog and Digital Circuits	CPCB
	Signals and Systems	COMM
	Discrete Mathematics/Structures	MN
	Linear Algebra	MN
	Object Oriented Programming	PROG
	Programming Fundamentals	PROG
	Data Structures and Algorithms	PROG
	Technical Writing and Presentation	TWP
	Microprocessor Systems	EMBD
	Numerical Methods	MN
Junior	Applied Probability and Statistics	MN
	Control Systems	MN/EMBD
	Digital Signal Processing	MN/COMM
	Electromagnetic Theory	COMM
	Analog and Digital Communications	COMM
	Antenna Systems	COMM
	Introduction to Robotics	EMBD
	Operating Systems	PROG
	Power Transmission and Distribution	PS
	Electric Machinery Fundamentals	PS
	Power System Analysis and Design	PS
Senior	Introduction to VLSI Design	CPCB
	Electrical Instruments	CPCB
	Integrated Electronic Circuits	CPCB
	Industrial Electronics	CPCB
	Power Electronics	CPCB/PS
	High Voltage Engineering	PS
	Renewable Energy Systems	PS
	Design of Electrical Machines	PS
	Power System Protection	PS
	Introduction to Smart Grids	COMM
	Satellite Engineering	COMM
	Wireless Communications	COMM
	Microwave Engineering	COMM
	Electromagnetic Compatibility	COMM
	Optical Circuits and Systems	MN/PROG
	Digital Image Processing	PROG
	Database Engineering	PROG
	Introduction to Machine Learning	PROG
	Computer Networks	PROG
	Software Construction	EMBD
	Artificial Intelligence	TWP
	Computer Architecture	TWP
	Project Management	TWP
	Thesis Writing (Capstone Project)	

TABLE IV

EXTENSIVE LIST OF ~250 TOOLS DEVELOPED BY THE COMMUNITY TO FACILITATE ECE EDUCATION

No	Software	Pub. after 2010	Offline	Free
Mathematical and Numerical Analysis (MN) Mathematical Analysis				
1	GeoGebra [9]	✔	✔	✔
2	GNU Octave [9]	✔		
3	GraphMonkey [10]		✔	✔
4	Gretl [11]	✔	✔	✔
5	Kig [12]		✔	✔
6	Maple [13]	✔	✔	
7	Mathematica [9]	✔		

No	Software	Pub. after 2010	Offline	Free
8	Mathworks MATLAB [14]	✓	✓	
9	OenEPI [15]	✓	✓	✓
10	OpenEuclide [16]		✓	✓
11	PSPP [17]	✓	✓	✓
12	SageMath [18]	✓	✓	✓
13	Scilab [9]	✓	✓	✓
14	Shogun [19]	✓	✓	✓
15	SMathStudio [20]	✓	✓	✓
16	wxMaxima [21]	✓	✓	✓
	Finite Element Analysis			
17	Agros2D [23]	✓	✓	✓
18	Calculix [24]	✓	✓	✓
19	CodeAster [25]	✓	✓	✓
20	COMSOL Multiphy [26]	✓	✓	
21	deal.II [27]	✓	✓	✓
22	DIANAFEA [28]	✓	✓	
23	DUNE [29]	✓	✓	✓
24	Elmer [30]	✓	✓	✓
25	F Enics Project [31]	✓	✓	✓
26	FreeCAD [33]	✓	✓	✓
27	Free Fem++ [34]	✓	✓	✓
28	Get FEM++ [35]	✓	✓	✓
29	GiD [36]	✓	✓	✓
30	Hermes Project [37]	✓	✓	✓
31	HyperMesh [38]		✓	
32	JCM suite [39]	✓	✓	
33	JMAG [40]	✓	✓	
34	Julia FEM [41]	✓	✓	✓
35	LS-DYNA [42]	✓	✓	
36	MFEM [43]	✓	✓	✓
37	MoFEM JosePH [44]	✓	✓	✓
38	OOFEM [45]	✓	✓	✓
39	Open FOAM [46]	✓	✓	✓
40	Range Software [47]	✓	✓	✓
	Programming (PROG) C/C++ Development			
41	Anjuta [48]	✓	✓	✓
42	Code::Blocks [49]	✓	✓	✓
43	CodeLite [50]	✓	✓	✓
44	Eclipse IDE (C/C++) [9]	✓	✓	✓
45	GNAT Studio [51]	✓	✓	
46	JetBrains Clion [52]	✓	✓	
47	Kdevelop (C/C++) [8]	✓	✓	✓
48	NetBeans C/C++ pack	✓	✓	✓
49	Oracle Solaris Studio [8]	✓	✓	
50	Qt Creator [9]	✓	✓	✓
51	Rational Soft. Arch [53]	✓	✓	
52	Ultimate++ the IDE [54]	✓	✓	✓
	C# and Visual Basic Development			
53	MonoDevelop [55]	✓	✓	✓
54	Rider [56]	✓	✓	
55	Understand (C♯) [57]	✓	✓	
56	Xamarin Studio [58]	✓	✓	
	JAVA Development			
57	BlueJ [8]	✓	✓	✓

No	Software	Pub. after 2010	Offline	Free
58	Dr Java [59]	✓	✓	✓
59	Eclipse IDE (JAVA) [9]	✓	✓	✓
60	Greenfoot [60]	✓	✓	✓
61	IntelliJ IDEA Com [61]	✓	✓	✓
62	JBuilder [62]		✓	
63	jGRASP [63]	✓	✓	✓
64	NetBeans JAVA pack [62]	✓	✓	✓
65	le Jdeveloper [64]	✓	✓	
66	Understand (JAVA) [66]	✓	✓	
	Python Development			
67	Anaconda [8]	✓	✓	✓
68	Eric [8]	✓	✓	✓
69	IDLE [9]	✓	✓	✓
70	KDevelop (Python) [8]	✓	✓	✓
71	Komodo (Python) [67]	✓	✓	
72	PyCharm [8]	✓	✓	✓
73	Jupyter [68]	✓	✓	✓
74	Thonny [8]	✓	✓	✓
	Ruby Development			
75	Aptana Studio 3 [69]	✓	✓	✓
76	Komodo IDE (Ruby) [70]	✓	✓	
77	NetBeans (Ruby) [71]	✓	✓	✓
78	RubyMine [72]	✓	✓	
	Tcl/Tk Development			
79	Komodo IDE [73]	✓	✓	
80	VTCL [74]	✓	✓	✓
	Perl Development			
81	Eclipse EPIC [9]		✓	✓
82	KomodoIDE [73]	✓	✓	
83	NetBeans (Perl) [71]	✓	✓	✓
84	Padre - the Perl IDE [75]		✓	✓
85	PerlEdit [76]			
	HTML/CSS/Javascript Development			
86	Aptana Studio 3 [69]	✓	✓	✓
87	BlueGriffon [82]	✓	✓	✓
88	Brackets [82]	✓	✓	✓
89	Eclipse WTP [9]	✓	✓	✓
90	KompoZer [77]	✓	✓	✓
91	NetBeans packs [71]	✓	✓	✓
92	NVU [78]		✓	✓
93	Quanta Plus [82]		✓	✓
94	Sea Monkey [79]	✓	✓	✓
95	WebStorm [80]	✓	✓	
	PHP Development			
96	Eclipse PDT [9]	✓	✓	✓
97	PHPStorm [81]	✓	✓	
98	Adminer [82]	✓	✓	✓
99	Datazenit [83]	✓	✓	
100	DBeaver [84]	✓	✓	✓
101	DBVisualizer [85]	✓	✓	✓
102	Jack DB [86]	✓	✓	
103	Maria DB [87]	✓	✓	✓

No	Software	Pub. after 2010	Offline	Free
104	MySQL Workbench [88]	✔	✔	✔
105	Navicat [89]		✔	
106	Oracle SQL Dev [8]	✔	✔	✔
107	Percona Toolkit [90]	✔	✔	✔
108	phpMy Admin [91]	✔	✔	✔
109	SQLite [92]	✔	✔	✔
	LISP Development			
110	Emacspeak [93]	✔	✔	✔
111	GNU Emacs (LISP) [9]	✔	✔	✔
112	GNU Zile [9]	✔	✔	✔
113	JOVE [94]		✔	✔
114	Lispbox [94]	✔	✔	✔
115	LispWorks [94]	✔	✔	
116	Portacle [94]	✔	✔	✔
117	QuickLisp [95]		✔	✔
118	SBCL [96]	✔	✔	✔
119	SLIME [97]		✔	✔
120	Vanilla Lisp Shell [98]		✔	✔
121	Xemacs [99]	✔	✔	✔
	R Development			
122	RKWard [9]	✔	✔	✔
123	RStudio [100]	✔	✔	✔
	Code Editors			
124	Atom [8]	✔	✔	✔
125	BlueFish [101]	✔	✔	✔
126	Brackets [102]	✔	✔	✔
127	Geany [103]	✔	✔	✔
128	GNU Emacs [9]	✔	✔	✔
129	GNU nano [9]	✔	✔	✔
130	JED [104]	✔	✔	✔
131	jEdit [105]	✔	✔	✔
132	Komodo Edit [106]	✔	✔	✔
133	SlickEdit [107]	✔	✔	
134	Sublime Text [8]	✔	✔	✔
135	UltraEdit [108]	✔	✔	
136	Vim [8]	✔	✔	✔
137	Visual Studio Code [8]	✔	✔	✔
	Compilers			
138	ActivePerl interpreter (Perl) [109]	✔	✔	✔
139	ActiveTcl (Tcl/Tk) [110]	✔	✔	✔
140	FreeBASIC (BASIC) [111]	✔	✔	✔
141	GCC GNAT (ADA) [8]	✔	✔	✔
142	GNU Compilers (C/C++) [9]	✔	✔	✔
143	Gnu COBOL (COBOL) [9]	✔	✔	✔
144	javac (JAVA) [112]	✔	✔	✔
145	Mono (C♯) [113]	✔	✔	✔
146	NASM (Intel *86) [114]	✔	✔	✔
147	python (Python) [9]	✔	✔	✔
148	r-base [115]	✔	✔	✔
	Network Simulation Software			
149	Edraw [117]		✔	✔
150	Gns3 [9]	✔	✔	✔

No	Software	Pub. after 2010	Offline	Free
151	OMNeT++ [118]	✓	✓	✓
	Network Monitoring Software			
152	Icinga 2 [119]	✓	✓	✓
153	Nagios Core [120]	✓	✓	
154	Zabbix [121]	✓	✓	✓
155	Zenoss Core [121]	✓	✓	
	Circuit Analysis and PCB Design (CPCB) Schematic and PCB Design			
156	Eagle [122]	✓	✓	
157	FidoCadJ [123]	✓	✓	✓
158	Gerbv [124]	✓	✓	✓
159	Kicad [9]	✓	✓	✓
160	PCB Layout Tool [9]		✓	✓
161	Visolate [9]		✓	✓
162	CircuiTikZ	✓	✓	✓
163	XCircuit	✓	✓	✓
164	Fritzing [9]	✓	✓	✓
165	gEDA [9]	✓	✓	✓
166	Ktechlab [125]		✓	✓
167	SimulIDE [126]	✓	✓	✓
	Simulation Program with Integrated Circuit Emphasis (SPICE)			
168	HADES [127]	✓	✓	✓
169	ModelSim [128]	✓	✓	
170	Magic VLSI [9]	✓	✓	✓
171	GNU-Cap [9]	✓	✓	✓
172	GNU Spice UI [9]	✓	✓	✓
173	GTKWave [9]	✓	✓	✓
174	Gwave [9]	✓	✓	✓
175	LCSIM [129]		✓	✓
176	NetlistViewer	✓	✓	✓
177	Ngspice [130]	✓	✓	✓
178	Oregano [9]	✓	✓	✓
179	QSapecNG [131]	✓	✓	✓
180	Spice+ [132]		✓	✓
181	SpiceX		✓	✓
	Power Systems (PS)			
182	GridLAB-D [133]	✓	✓	✓
183	PyPSA [134]	✓	✓	✓
184	GridSim [135]		✓	✓
185	Penthode [136]	✓	✓	✓
186	RAPSim [137]	✓	✓	✓
187	Python Power Electronics [9]	✓	✓	✓
	Embedded Systems (EMBD) PIC Development Tools			
188	Gputils [138]	✓	✓	✓
189	MPLAB [139]	✓	✓	✓
190	SDCC [140]	✓	✓	✓
	ARM Development Tools			
191	Code Composer Studio [141]	✓	✓	✓
192	DENX ELDK [142]		✓	✓
193	Eclipse MCU [9]	✓	✓	✓
	Arduino Development Tools			
194	Arduino IDE [143]	✓	✓	✓
195	Processing IDE [144]	✓	✓	✓
	AVR Development Tools			
196	AVR toolchain [145]	✓	✓	✓
197	Simuavr [146]	✓	✓	✓

No	Software	Pub. after 2010	Offline	Free
	8051 Development Tools			
198	GNU 8085 Simulator [9]	✓	✓	✓
199	MCU 8051 IDE [9]	✓	✓	✓
200	SDCC [140]	✓	✓	✓
	Texas Instruments Development Tools			
	RISC-V Development Tools			
201	Eclipse MCU [9]	✓	✓	✓
202	FireSim [148]	✓	✓	
203	Jorlk [147]	✓	✓	
204	GEM5 [148]	✓	✓	✓
205	PQSE [149]	✓	✓	
206	RAR [148]	✓	✓	✓
207	Renode [150]	✓	✓	✓
208	RISCV-VP	✓	✓	✓
209	VLAB Works [148]	✓	✓	
210	SNIPER [148]	✓	✓	✓
211	Intel's PIN tools [148]		✓	✓
212	MARS [148]	✓	✓	✓
213	Spim [9]	✓	✓	✓
	Communication Systems (COMM)			
	Electromagnetic (EM) Simulation			
214	Angora	✓	✓	✓
215	gprMax	✓	✓	✓
	Antenna Design and Simulation			
216	MaxFEM	✓	✓	✓
217	Meep	✓	✓	✓
	Technical Writing and Presentation Skills (TWP)			
	Document Preparation Systems			
218	TeX Live [9]	✓	✓	✓
219	TeXstudio	✓	✓	✓
220	TeXmaker [9]	✓	✓	✓
221	Gummi	✓	✓	✓
222	Lyx	✓	✓	✓
223	GNU TeXmacs [9]	✓	✓	✓
224	Halibut	✓	✓	✓
225	Notabene	✓	✓	
	Word Processor			
226	GNU TeXmacs [9]	✓	✓	✓
227	Gummi	✓	✓	✓
228	Halibut	✓	✓	✓
229	Lyx	✓	✓	✓
230	Notabene	✓	✓	
231	TeX Live [9]	✓	✓	✓
232	TeXmaker [9]	✓	✓	✓
233	TeXstudio	✓	✓	✓
	Spreadsheet Editor			
234	CalligraSheets	✓	✓	✓
235	LibreOffice calc [8]	✓	✓	✓
236	Pyspread	✓	✓	✓
237	WPS Office Spreadsheets	✓	✓	✓
	Presentation Program			
238	Beamer	✓	✓	
239	CalligraStage	✓	✓	✓
240	LibreOffice Impress [8]	✓	✓	✓
241	Whyte Board		✓	✓
242	WPS Office Presentations	✓	✓	✓
	Diagram/Flowchart			
243	Dia	✓	✓	✓
244	Edraw Flowchart Software	✓	✓	✓
245	LibreOffice Draw [8]	✓	✓	✓
246	yEd	✓	✓	✓
	Reference and Citation			
247	JabRef	✓	✓	✓
248	KBibTeX	✓	✓	✓
249	Referencer	✓	✓	✓
250	Zotero	✓	✓	✓
	Project Management			
251	Gantt Project	✓	✓	✓
252	Gi	✓	✓	✓
253	GitKraken	✓	✓	✓
254	Jira	✓	✓	

No	Software	Pub. after 2010	Offline	Free
255	TaskJuggler	✓	✓	✓
	Virtual Machines (VMs)			
256	Parallels Desktop	✓	✓	
257	QEMU [9]	✓	✓	✓
258	VirtualBOX	✓	✓	✓
	Serial Monitor			
259	PuTTY [9]	✓	✓	✓
	Calculator			
260	Generic Mapping Tools	✓	✓	✓
261	Qalculate	✓	✓	✓
262	SpeedCrunch	✓	✓	✓
	Unit Converter			
263	ConvertAll	✓	✓	✓
264	Gonvert	✓	✓	✓
265	MultiConvert	✓	✓	✓
	Help and Learning Resources			
266	Artha	✓	✓	✓
267	Golden Dict	✓	✓	✓
268	Resistor Color Calculator	✓	✓	✓
269	StarDict	✓	✓	✓

4. CONCLUSION

COVID-19 pandemic and subsequent intermittent lock downs gave rise to wide-spread use of virtual classrooms, raising awareness among educators pertaining to the dire need to enhance quality of e-learning. As engineering disciplines require extensive lab work, there is a need for advanced solutions that may fill necessary gaps and provide quality education in this hard time. Hence, the authors of this study, through their extensive discussions and experiences spanning Pakistan, Turkey, and USA were able to appreciate the need to (i) introduce Linux OS as a necessary component within the ECE curriculum and (ii) showcase the wide variety of tools available in the Linux ecosystem that gracefully cover the entire four-year undergraduate program.

It is worth highlighting that both Android and iOS dominate the mobile market. Statista reports that Android holds about 70% of the global mobile market share, with iOS accounting for around 28%, leaving little room for competitors. With over 6.8 billion smartphone users worldwide, this dominance would likely grow as smartphones become increasingly affordable and accessible. Moreover, the combined ecosystems of Android and iOS support over 8 million apps on their app stores, with revenue from mobile apps projected to surpass $935 billion by the end of 2025. Innovations, such as artificial intelligence (AI) integration, 5G connectivity, and enhanced user interfaces are driving adoption, while these platforms' seamless integration with wearables, IoT devices, and cloud services ensures their continued relevance. This combination of widespread adoption, cutting-edge technology, and revenue potential underscores why Android and iOS are poised for sustained growth in the coming years.

Engineering and CS students may leverage this growing popularity by developing experimental tools and applications on Android and iOS platforms to enhance their learning and career prospects. By designing apps that utilize emerging technologies, such as AI, machine learning, augmented reality, or blockchain, students may gain practical experience in high-demand fields. For instance, creating educational tools, simulations, or productivity apps can allow students to experiment with APIs, cross-platform development, and user interface design. These platforms' vast user bases and developer-friendly resources, such as Android Studio and Apple's Xcode, provide excellent opportunities for rapid prototyping and real-world testing. Additionally, publishing apps on Google

Play or the App Store enables students to showcase their work globally, building professional portfolios and potentially earning revenue. Ultimately, working on Android and iOS not only equips students with relevant technical skills but also helps them address real-world challenges in industries increasingly shaped by mobile technologies.

Lastly, through this study, the authors hope the wider community may benefit from Linux's rich ecosystem and help ECE learn globally, and perhaps expand to Android and iOS in order to enhance their career prospects for the next decade.

CONFLICT OF INTEREST

The author of the manuscript has no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

DATA AVALIABILITY STATEMENT

The data associated with this study will be provided by the corresponding author upon request.

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