JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice
Website: www.jriiejournal.com ISSN 2520-7504 (Online) Vol.10, Iss.3, 2026 (pp. 655 - 663)

Mapping University-Industry Partnership Models in Electrical and Electronics Technology Education: A Systematic Review

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Abstract*: With increasing complexity of modern electrical and electronic industries, there is a strong demand in the industry for the universities to produce graduates who have competencies required by the industry in response to its evolving needs. To connect academic preparation with workplace needs, strategic approaches have come to light in the form of university-industry partnerships (UIPs). That said, there is a varying and context-specific grasp of the models of partnerships that are used, especially in Electrical and Electronics Technology Education (EET). This systematic review documents the most common partnerships models between universities and industry that are relevant to EET programmes based on 78 peer-reviewed articles, institutional reports and policy documents published between 2015 and 2024. The review follows PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, and seven basic models of partnerships are identified: cooperative education, industrial attachment/ internship schemes, joint research and development partnerships, curriculum co-design, technology transfer and spin-offs, industry advisory boards, and sponsored chairs and endowments. Results show that in developed economies curricular co-design and joint research and development models are those most likely to lead to employability of graduates, while in Sub Saharan Africa, the cooperative education and industrial attachment models are the most commonly used. Bureaucratic rigidity, issues with intellectual property rights, monetary challenges and cultural misalignment are recognized as common challenges in all models. The paper ends with a suggested integrative framework and practical suggestions for university decision makers, industry and education policymakers.*

Keywords*: university-industry partnership, electrical and electronics technology education, cooperative education, curriculum co-design, TVET, graduate employability, systematic review, Nigeria*

How to cite this work (APA):

Akinduro, I. R. & Adeoti A. O. (2026). Mapping University-Industry Partnership Models in Electrical and Electronics Technology Education: A Systematic Review. *Journal of Research Innovation and Implications in Education, 10*(3), 655 – 663. **https://doi.org/10.59765/uy7g**

1. Introduction

Competency profiles for graduates in electrical and electronics-related fields are now being redefined, as a consequence of the increasingly rapid pace of technological change associated with the Internet of Things (IoT), automation, artificial intelligence and renewable energy transition (Schwab, 2016; Philbin, 2020). Electrical and Electronics Technology Education (EET) programs at universities have to grapple with the dual challenge of maintaining academic rigor while enhancing students' skills with industry-relevant, practical skills that are expected in the modern workplace (Renganathan et al., 2021). A common issue that has been reported globally across sub-Saharan Africa, Southeast Asia and parts of OECD countries (Mehta & Mehta, 2022; World Bank, 2022) is that graduates are not equipped with the skills that employers are looking for.

University-industry partnerships (UIPs) have been recommended as one of the structural measures to address this gap for years (Ankrah & Al-Tabbaa, 2015). These partnerships range from informal to formal and involve collaboration between universities and industrial organisations for a variety of goals and outcomes such as improved graduate programs, technology transfer, workforce development, and innovation creation (Perkmann et al., 2021). The applied nature of EET makes the UIPs essential since they will link theoretical knowledge of circuit theory, power systems, digital electronics, and control engineering with design, installation, testing, and troubleshooting skills (Olabiyi & Uwaifo, 2020).

The literature also shows that the link between partnership models and EET programmes exists but is very weak in the context of African universities, since there does not seem to be a systematic, discipline-specific mapping of the models of partners that can be applied to EET programmes. The current reviews on EET tend to be either general over STEM education without delving deeper into EET (Nair et al., 2022) or to be geographically limited to either European or North American contexts rather than engaging with the challenges and opportunities of developing economies (Acheampong & Haffar, 2021). This gap makes it difficult for university leaders, curriculum planners and policymakers to make informed decisions regarding the best and most effective configuration of partnerships for their institutions.

This is the purpose of the present systematic review, which aims to map in a comprehensive way the dominant UIP models that have been reported in the relevant literature for EET, analyze the main characteristics of these models, the contexts in which they have been applied, the reported results, and the barriers associated with these models. The review is guided by the following research questions:

1. What are the prevalent university/industry partnership models reported in the Electrical and Electronics Technology Education literature?
2. What are the enabling conditions, outcome, and key features of each of the identified partnership models?
3. What are the challenges to the successful implementation of UIPs in EET programmes, especially in the context of developing countries?
4. What are the current research strengths and weaknesses in the literature that need further investigation through empirical research?

The results of this review are designed to be used in debate and in policy development at a global level in TVET.

2. Literature Review

2.1 Conceptual Framwork

The theoretical framework for this review relies on three complementary theories: the Triple Helix Model, Human Capital Theory and Constructivist Learning Theory. These frameworks give us a multidimensional perspective on why and how universities and industries work together in education.

2.1.1 The Triple Helix Model

The Triple Helix Model was developed by Etzkowitz and Leydesdorff (1995), subsequently expanded by Etzkowitz and Zhou (2017), to outline the changing dynamics between the three sectors, the university, the industry and the government, as partners in the innovation and knowledge chain. Since the EET perspective is interested in the role of the university as a knowledge producer beyond that, it is especially instructive for this model to define the universities as entrepreneurial actors that can initiate and perpetuate productive partnerships with industry. The model proposes that the synergies created by all three helices (academica, industry and government) will lead to technological innovation and improvement in educational quality (Etzkowitz & Zhou, 2017). The Triple Helix Model has also been adapted to examine partnerships that are created in African higher education contexts where government policies have a pivotal role in driving the scope and sustainability of UIPs (Acheampong & Haffar, 2021).

2.1.2 Human Capital Theory

The Human Capital Theory, which builds on the concept of Becker (1964) and was elaborated by modern-day education economists, suggests that expenditure on education and training offers tangible benefits, specifically in the form of enhanced productivity, income and economic growth. In this context, UIPs are tools that enable universities to build the value of the human capital of their graduates by embedding competencies relevant to the industry in academic courses (Mehta & Mehta, 2022). According to empirical evidence from various countries, the starting salaries of graduates from industry-oriented programmes are higher than those of graduates from traditional programmes, and graduates from industry-oriented programmes have a more rapid career advancement rate than graduates from traditional programmes (Coll & Zegwaard, 2020; Oluwatayo & Ojo, 2021).

2.1.3 Constructivist Learning Theory

According to Vygotsky (1978) social constructivist approach to technical education, meaningful learning takes place in real-world problems that are set in social and professional situations. This theory is put into practice through UIPs, especially the cooperative education and industrial attachment models, which allow students to learn by doing, watching, and mentoring in industry (Renganathan et al., 2021). This theoretical match-up serves to support the pedagogical argument for UIPs that goes beyond matching skills, and makes them a key element of the epistemology of technical education.

3. Methodology

The methodology used in this study was the systematic review method that was designed based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Page et al., 2021). The systematic review approach was chosen as it was the most appropriate method for synthesising a large and heterogeneous body of literature on UIPs in EET as it ensures rigour, transparency and replicability.

Studies were considered if they: (a) focused on UIPs in EET, engineering technology or related technical fields; (b) were published in English in peer-reviewed journals, conference proceedings or institutional reports; (c) were published between 2015 and 2024; and (d) included enough detail to identify partnership models, outcomes, or obstacles. Those studies that had only medical, agricultural or non-technical study areas or were opinion pieces lacking empirical or documentary evidence were excluded.

The first search of the database was carried out and resulted in 1247 records. Duplicates (n = 318) were removed and titles and abstracts were screened, excluding 721 that were determined to be irrelevant. The remaining 208 articles were assessed for eligibility and 78 studies were included. The Mixed Methods Appraisal Tool (MMAT) was used to perform quality appraisal of studies, based on the quality of the methodology, data rigour, and relevance of findings (Hong et al., 2018).

A structured template was used to extract data that included: study context; partnership model type; key features, reported outcomes, barriers identified, and enabling conditions. Thomas and Harden (2008) used thematic synthesis to find patterns, cluster the findings into model categories and create analytical themes at a higher level. NVivo 14 software was used to manage coding, NVivo is a computer software package produced by Lumivero designed for qualitative and mixed-methods data analysis

4. Results and Discussion

4.1 Partnership Models in EET

The thematic synthesis identified seven major university-industry partnership models documented in the EET literature. Table 1 provides a comparative overview of these models, their key features, institutional examples, and supporting references.

Table 1: University-Industry Partnership Models in Electrical and Electronics Technology Education

Model	Key Features	Examples	Key References
Cooperative Education (Co-op)	Alternating academic and work terms; structured industry placements	University of Waterloo (Canada); KNUST (Ghana)	Acheampong & Haffar (2021); Coll & Zegwaard (2020)
Industrial Attachment / SIWES	Mandatory internship supervised by both university and industry mentors	Nigerian universities; South African universities	Olabiyi & Uwaifo (2020); Oluwatayo & Ojo (2021)
Joint Research & Development	Collaborative R&D projects; shared funding and IP	MIT-IBM Watson AI Lab; ETH Zurich-ABB	Ankrah & Al-Tabbaa (2015); Perkmann *et al*. (2021)
Curriculum Co-Design	Industry stakeholders co-develop course content and learning outcomes	Germany's dual education system; polytechnics in Malaysia	Renganathan *et al*. (2021); Mehta & Mehta (2022)
Technology Transfer & Spin-offs	University IP licensed to industry; startup incubation	Stanford OTL; University of Lagos Tech Hub	Etzkowitz & Zhou (2017); Ismail *et al*. (2020)
Industry Advisory Boards	Structured employer input into programme governance and review	IEEE-accredited EET programmes globally	Nair *et al*. (2022); Ramaswamy *et al*. (2020)
Sponsored Chairs & Endowments	Industry funds professorial chairs, labs, scholarships	Siemens Chair programmes; Shell Petroleum Endowment Fund (Nigeria)	Slaughter & Rhoades (2020); Olusanya *et al*. (2021)

4.1.1 Cooperative Education (Co-op)

One of the most formalised UIP is cooperative education, which involves alternation between blocks of academics and blocks of structured, paid work experience in industry (Coll & Zegwaard, 2020). Co-op programmes started in the early 20th century in North America, and are more established in Canadian, Australian and Ghanaian universities (Acheampong & Haffar, 2021). Co-op placements in EET are generally arranged in conjunction with electrical utilities, telecommunications industries, electronics manufacturing companies, and energy companies, giving students opportunities to see settings that they are unlikely to encounter in academic laboratories.

Numerous studies have shown that co-op members benefit in a positive way. In its cross-country research, Coll and Zegwaard (2020) discovered that co-op students were significantly more likely to be employed six months after graduation and more confident in their ability to apply theoretical knowledge to the real world. The same finding was reported by Acheampong and Haffar (2021) in their study of co-op graduates of engineering technology students in Ghana, who found that the students' competency scale scores for workplace readiness were significantly higher than those of the control students on three validated scales.

4.1.2 Industrial Attachment and SIWES

The Students Industrial Work Experience Scheme (SIWES) is the most institutionalised approach of UIP in technical education in the Nigerian and wider West African context. SIWES was started by Industrial Training Fund (ITF) in 1973 and is compulsory for EET students in accepted programmes within the programme to undergo at least 24 weeks of supervised industrial training (Olabiyi & Uwaifo, 2020). Mandatory attachment schemes are in place in South Africa, Kenya and Ghana.

However, a survey of 240 EET graduates from six Universities in Nigeria by Oluwatayo and Ojo (2021) revealed that only 43% of the respondents rated the quality of SIWES supervision as satisfactory or above. The key areas of weakness found were limited industry mentor training, lack of congruence between industry placements and students' specialisations and inconsistent supervision while in the university. The results agree with those of Olabiyi and Uwaifo (2020) that the effectiveness of SIWES outcomes is significantly influenced by institutional capacity and the quality of university-industry linkages.

4.1.3 Joint Research and Development

Collaborative R&D projects between industry and academic institutions in EET usually are projects related to product development, improvement of processes, applied research on power electronics, embedded systems, smart grid solutions, or integration of renewable energy (Perkmann et al., 2021). Such partnerships are well known in Europe and North America, with industry partners sharing the research costs, access to their proprietary equipment, and assisting in research design, in return for priority access to new technologies.

Perkmann et al. (2021) carried out a comprehensive bibliometric study of 1,500 UIP studies, revealing that joint R&D partnerships yielded the largest number of patents and commercialisable innovations as compared to any other type of partnership. The study, however, also pointed out that such collaborations are skewed towards high-income country research hubs, and were almost entirely lacking in Sub-Saharan Africa. Ismail et al. (2020) explained this imbalance on the basis of various factors such as: the level of research infrastructure, IP legal frameworks, and the lesser strength of innovation ecosystems in developing economies.

4.1.4 Curriculum Co-Design

Curriculum co-design is a process that includes systematic involvement of industry actors in curriculum content, learning outcomes, and assessment systems development, review and improvement (Renganathan et al., 2021). It is institutionalised in Malaysia's polytechnics through industry panels, which are held every two years to examine competency frameworks, and in Germany's highly respected dual education system, where industry chambers have special statutory status to be part of the curriculum governance process (Mehta & Mehta, 2022).

A curriculum co-design effort undertaken in an electronics technology programme in Malaysia was evaluated by Renganathan et al. (2021) and resulted in a 18% increase in the employment of graduates within two years of implementation, and a corresponding 22% increase in the satisfaction scores of employers with regard to the graduates' technical competency. But the authors pointed out that the model's success hinged on the level of industry involvement programmes, where industry partners only received advisory functions and no power to make decisions, demonstrated little improvement.

4.1.5 The technology transfer and spin-offs.

There are three types of technology transfer partnerships: commercialization of the IP generated by the universities via licensing, joint ventures, or spin-off companies (Etzkowitz & Zhou, 2017). Technology transfer is especially relevant in instances of power conversion systems, IoT devices, sensor technologies, and electronic control systems in EET. Ismail et al. (2020) conducted a study on technology transfer activities in 45 universities in Malaysia and Nigeria and revealed that although technology transfer legal frameworks were generally present, the capacity of the universities to negotiate and manage IP agreements was still significant obstacle, especially in public universities.

4.1.6 Industry Advisory Boards

Industry advisory boards (IABs) is a formal governance group where the employer representatives advise the university departments on the relevance of the programmes, new skills demanded by the industry and industry trends (Nair et al., 2022). IABs have been widely recommended by international accreditation bodies such as Accreditation Board for Engineering and Technology (ABET) and have been mandated by Nigerian Universities Commission (NUC) for accreditation of EET programmes. Ramaswamy et al. (2020) found that EET programmes that had active, regularly convened IABs had more rapid cycles of curriculum changes and reported greater employer satisfaction with the competencies of graduates, than those that lacked functional advisory boards.

4.1.7 Sponsored Chairs and Endowments

Another type of UIP is industry-sponsored professorships, research chairs, and equipment endowments, where industrial organisations donate financial resources to universities in return for access to a talent pipeline, brand recognition, and research priority (Slaughter & Rhoades, 2020). In Nigeria, endowment funds have been set-up at some universities by Shell Petroleum Development Company and Dangote Group, as part of the funding of laboratory equipment in the EET departments. (Olusanya et al., 2021). However, while these arrangements help meet important gaps in resources, Slaughter and Rhoades (2020) warn that over-dependency on corporate sponsorship can undermine academic autonomy and research and curricular focus on marketable and profitable topics at the expense of those that serve a public interest.

4.2 Barriers to Effective University-Industry Partnership in EET

Across the 78 reviewed studies, a consistent set of barriers to effective UIP implementation was identified. Table 2 organises these barriers thematically.

Table 2: Barriers to University-Industry Partnership Implementation in EET

Challenge Category	Specific Barriers	Key References
Structural & Bureaucratic	Rigid university regulations; slow curriculum approval processes; misaligned academic calendars	Ankrah & Al-Tabbaa (2015); Olabiyi & Uwaifo (2020)
Financial & Resource Constraints	Inadequate funding; lack of industry investment in education; poor laboratory infrastructure	Oluwatayo & Ojo (2021); World Bank (2022)
Cultural & Attitudinal Differences	Academic-industry communication gaps; distrust; differing timelines and priorities	Perkmann *et al*. (2021); Philbin (2020)
Intellectual Property Issues	Unclear IP ownership; reluctance to share proprietary technology; legal disputes	Ismail *et al*. (2020); Etzkowitz & Zhou (2017)
Geographical & Infrastructure	Poor internet connectivity; distance between institutions and industries in developing countries	Acheampong & Haffar (2021); UNESCO (2021)

Bureaucratic rigidity in university governance was the most common barrier reported in all reviewed studies, reported in 67% of articles included in the sample (Ankrah & Al-Tabbaa, 2015; Olabiyi & Uwaifo, 2020). In many universities in Nigeria and West Africa it takes 18 – 36 months before any curriculum is approved, but industry demands for technology and skills are changing at a rapid pace and this is incompatible with such a slow process. Philbin (2020) also reported that there are ongoing tensions stemming from cultural differences between research and industry partners, such as varying expectations on time horizons, people communication and performance measurement, that complicate the development of even good intentions to pursue partnership arrangements between the two worlds.

The second most common obstacle was financial restrictions, especially in the context of developing countries. The World Bank (2022) estimated that less than 2% of the total budgets of the universities in Sub-Saharan Africa is spent on industry engagement activities compared to 8.4% for OECD universities. This resource imbalance reduces the potential and viability of UIPs in EET, and most institutions have not been able to establish systematic institutionalised partnership, instead they have informal ad hoc arrangements (Acheampong & Haffar, 2021).

Creating conditions and practices for success.

Another set of conditions emerged from the literature reviewed that would facilitate successful implementation of UIP. The commitment from within the institution, specifically the leadership, was consistently found to be the most important success factor (Perkmann et al., 2021; Nair et al., 2022). Significant links between industry and the institutions existed, with those having a dedicated office or unit for industry liaison and having clear IP policies and senior administrators with industry experience having significantly higher rates of successful partnership formation and maintenance.

The second most important enabling condition was government policy frameworks. Countries that have specific laws that address UIPs, including Malaysia's Industry-University Partnership Framework, South Korea's Industry-Academy Cooperation Foundation Act and Brazil's Innovation Law, had greater rates of formalised partnerships and more balanced distribution of partnerships benefits between academic and industrial participants (Etzkowitz & Zhou, 2017; Mehta & Mehta, 2022). On the other hand, in countries where UIP policy is weak and/or not developed in a systematic manner, partnerships depend mainly on individual faculty contacts, which are very fragile and do not lead to sustainability.

The industry linkages were more productive and sustained with the presence of industry liaison officers at the programme level, regular structured engagement activities like career fairs, industry seminars, and industry networking alumni networks (Renganathan et al., 2021; Ramaswamy et al., 2020).

4.3 Gaps and Future Directions

This systematic review highlights some key areas where research into UIPs in EET is lacking and needs to be prioritised.

Firstly, there is a conspicuous lack of research on EET programmes in West Africa and Nigeria in particular in peer-reviewed UIP research. Only 9 (11.5%) of the 78 studies included had the focus on Nigerian institutions and none of the studies conducted a full programmatic analysis of UIP models in various universities. This gap is important and significant in the development of policies as Nigeria is having the highest number of students from engineering and the environment in Africa (NUC, 2023).

Second, there are no studies of career outcomes for graduates from EET programmes with different UIP configurations that have followed them over time. Cross section employer satisfaction surveys give some evidence but do not allow for causal links between specific partnership models and long term career outcomes. Longitudinal tracer studies with a 5-10 year follow-up after graduation are needed to determine which UIP models yield more lasting employability outcomes.

Third, the review identified little empirical focus on digital and virtual UIP that have emerged or have gained momentum during the COVID-19 pandemic. Online industry mentorship platforms and online tools for curriculum co-design, as well as virtual internships, are among the newer forms of UIP that are not fully developed nor well documented in terms of theory and practice (UNESCO, 2021).

Fourth, few comparative studies have been found in the literature to compare UIPs in EET in public and private universities and/or universities of technology and conventional universities. These comparative analyses would offer valuable detail to inform policy recommendations that would address specific institutional contexts.

This Integrative Framework for UIP in EET was suggested.

This review introduces an Integrative University-Industry Partnership Framework for EET (IUIP-EET) based on the synthesis of identified models, enabling conditions and barriers. The effective UIPs as defined in the framework are at four connected levels:

i. Macro Level (Policy Environment): Government legislation, national qualification frameworks, accreditation requirements and funding mechanisms that provide the enabling environment for UIPs. Explicit and stable policy support in national governments and/or regulatory bodies like the NUC and the Industrial Training Fund (ITF) in Nigeria are essential for effective UIPs.

ii. Meso Level (Institutional Structures): University level offices for industry liaison, clear IP and partnership agreement templates, senior management commitment, dedicated budget allocations for industry engagement activities. ABET aligned advisory board governance structures should be used as a starting point for institutional governance.

iii. Micro Level (Programme Operations): Curriculum co-design processes, industrial attachment co-ordination and supervision, and alumni networking with industry. EET departments need to create annual industry consultation forums and develop real-time tracking systems of their graduates.

iv. Individual Level (Faculty and Student Agency): Faculty involvement in industry research, student involvement in competitions and hackathons, and personal networking. At this level, low cost high impact mechanisms are Faculty sabbaticals in industry and industry guest lecture programmes.

The IUIP-EET framework highlights the need for actions at all four levels to be coherent and reinforcing for sustainable UIPs in EET. There is weak and short-lived effect from isolated interventions like introducing industrial attachment but failing to provide it with follow-through mechanisms or from setting up advisory boards without institutional follow-through mechanisms (Perkmann et al., 2021; Nair et al., 2022).

5. Conclusion and Recommendations

5.1 Conclusion

The results of this systematic review have identified seven main models of university-industry partnership (UIP) that are relevant to Electrical and Electronics Technology Education (EETE) cooperative education, and have examined their features, outcomes, enabling factors and barriers from a sample of 78 peer-reviewed and grey literature sources published between 2015 and 2024.

The review provides confirmation that there is no one best partnership model – the success or failure of particular models depends strongly on the institutional setting, national policy frameworks, availability of resources and mutual commitment of academic and industrial partners. The most immediate priorities for the improvement of the quality of SIWES programmes in Nigerian and other West African Universities are to enhance the quality assurance mechanisms of existing SIWES programmes, institutionalise industry advisory boards with effective decision making powers and engage in curriculum co-design programmes with key EET employers. The draft IUIP-EET framework provides a systematic analytical approach for the University administrators, curriculum planners, accreditation agencies and Government ministries to analyse and enhance the university's UIP arrangements. Its multi-level structure recognises that only systemic rather than piecemeal interventions can create sustainable, high impact partnerships. Long-term tracer studies of EET graduates, comparative studies on UIP models by the institutional type and empirical studies on new digital partnership forms should be emphasized in future research. The low number of representations from Nigerian and West African institutions in the global UIP literature also poses an opportunity to regionally based researchers to make original and impactful contributions to this space.

5.2 Recommendations

1. University leadership should create or reinforce dedicated Industry Liaison Offices that have appropriate mandates, staffing and budget to proactively develop and manage partnerships.

2. It is important that industry put in significant investment to co-design curriculum by having senior technical staff members on university advisory boards and to be involved meaningfully in programme review processes.

3. Government and policy makers should create specific legislation for university-industry partnership that offers tax incentives for industry investment in EET programmes and ensures transparency on IP ownership regarding collaborative research.

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