JOVES (Journal of Vocational Education Studies)
VOL 9, No. 1, 2026, pp. 145- 162
pISSN: 2614-7483 pISSN: 2614-7475 https://doi.org/10.12928/joves.v9i1.13721

Design of Teaching Materials for Hybrid Electric Vehicles Fundamentals in Vocational Education: a Systematic Literature Review

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ARTICLE INFO

Article history
Received: Jun 21, 2025
Revised: Oct 14, 2025
Accepted: Oct 24, 2025

Keywords
Hybrid Electric Vehicle
Digital Technology Integration
Systematic Literature Review
Teaching Materials
Vocational Education

ABSTRACT

Transition toward electric vehicles creates new demands for vocational education, particularly in preparing students with Hybrid Electric Vehicle (HEV) competencies. Although crucial, structured and pedagogically based HEV fundamental teaching materials remain underexplored. This study analyzes global research trends in designing HEV teaching materials through a Systematic Literature Review (SLR) of 25 international studies published over the last two decades. Analysis focuses on three main aspects: (1) global development trends of HEV teaching materials, (2) digital technologies utilized in their development, and (3) the most frequently taught fundamental HEV concepts in vocational education. The results show a developmental trend shifting toward integrating digital project-based learning and simulations to facilitate complex conceptual understanding. Dominant digital technologies include virtual laboratories & experimental platforms (48%), interactive multimedia & simulation-based learning (28%), and e-learning & digital curriculum systems (24%), which are proven to increase learning interactivity and effectiveness. The most frequently taught concepts cover powertrain architecture & configuration (24%), energy management & control strategies (16%), and vehicle dynamics & performance (16%). Pedagogically, these materials are integrated through Project-Based Learning (PBL), simulation-based instructions, and direct laboratory experiences, aligning with competency-based vocational education. This study concludes that the future of HEV education relies on the synergistic integration of digital technology, authentic problem-solving, and multidisciplinary collaboration. This integration enhances conceptual understanding and applied technical competencies, supporting the broader goal of sustainable automotive education in the electrification era.

Introduction

Global transition towards transportation sustainable and electrified has change industry automotive and systems education related in a way in depth. Hybrid Electric Vehicles (HEV), as technology connector between machine conventional internal combustion and propulsion electricity full, is field studies important in education modern (Shahzad and Cheema, 2024) system integration electrical, mechanical, and control in HEV technology does not only need mastery technical but also competence interdisciplinary, digital literacy, and learning strategies adaptive, especially in education vocational, where participants educate prepared for involvement direct with industry (Ola, 2022; Yahya et al., 2024).

In some year recently, governments and industries around the world have speed up initiative related efficiency energy and reduction carbon, which creates request urge will power capable work design, maintain, and manage system Hybrid Electric Vehicle (Pandya et al., 2023; Said-Romdhane & Skander-Mustapha, 2025; Shibusawa & Xu, 2013). Demand this has push institution education for designing repeat curriculum and materials learning they, especially in the training program vocational and technical Nurjanah et al., (2022). However, even though relevance industry the more increase, development structured and based hev teaching materials pedagogy still fragmented and not consistent throughout institutions and regions.

Existing studies has explore education related to hev from various perspective, including modeling and simulation vehicles, development laboratory and prototype test site scale small, and environment learning based project (Fajri et al., 2016; Samonig et al., 2013; Steffen et al., 2022). Although initiatives this give outlook valuable about aspect technical or pedagogical certain, there are synthesis limited connecting efforts this to in cohesive understanding about how hev teaching materials are designed, what digital technologies are used, and the foundations conceptual and pedagogical what is the basis for it Lager et al., (2023). As a result , educators often lack framework comprehensive work for guide design systematic source power HEV learning in the environment vocational Brusaglino et al., (2014).

More further research previously tend emphasize modeling system technical or description level curriculum, instead explore how digital devices, content conceptual, and approach pedagogical interact for support development competence students. The gap this highlight the need Systematic Literature Review (SLR) which is not only map global trends in development hev teaching materials but also identify digital technology, core concepts, and integration the most frequent pedagogical adopted in the field this.

Therefore that, study this aim for give synthesis comprehensive from existing global literature about design teaching materials for the fundamentals of Hybrid Electric Vehicles (HEV) in education vocational . With review studies international, research this identify patterns, challenges, and innovations main in development source power HEV learning. In specific, review this discuss question research (RQ) below : How trend development HEV teaching materials are reflected in global literature? What types of digital technologies are often used in development HEV teaching materials, and what the difference? Concept key what is most often discussed in HEV teaching materials, and how draft the integrated in a way pedagogical?

Through questions this study this make an effort build runway conceptual for designing effective and based HEV teaching materials technology , which is in harmony with need participant educate vocation and demands industry mobility medium green develop.

Method

Search strategy

Study this is a systematic literature review that collects all over article with same topic from various source library. Focus main study this is how technology can help student study more effective in learning hybrid electric vehicles. Article data source taken from scopus. The page is machine search linked articles with various source articles all over the world, so coverage of data obtained wide and protected from articles whose data is biased Setyawan and Yanto, (2024). Articles that will be filtered in this systematic literature review is published articles from 2000 to 2025. Search article done with using keywords (" teaching" or "education" and "hybrid electric vehicle ") accessed on june 16, 2025. Appropriate search techniques with research topic use method Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) search consisting of from four step that is identification, screening, eligibility, and inclusion, so that give description transparent about the selection process Page et al., (2021). The prisma method is effective method used for conduct a systematic literature review of study with steps selection systematic to submitted articles Liberati et al., (2009).

Study selection

Criteria for inclusion or exclusion

Search journal narrowed down use criteria inclusion and exclusion, for focus effort search and ensure that only studies relevant considerations Lane and Kettler, (2019). Quality articles that will be investigated known as criteria inclusion, whereas characteristics articles that will be excluded

known as criteria exclusion Craig and Taswell, (2022). Articles that are not fulfil criteria inclusion for researched articles will excluded. Criteria inclusion and exclusion for this systematic literature review shown in Table 1. Articles included in criteria exclusion no including in material references in article this.

Table 1. Criteria inclusion and exclusion

Criteria	*Inclusion*	*Exclusion*
Topics researched	Hybrid Electric Vehicle	Besides hybrid electric vehicles
Year rise journal	2000 – to june 2025	Before 2000 & after june 2025
Document type	Articles and conference papers	Conference review, review, book chapter, book, short survey, retracted, note, erratum, data paper
Language used	Documents that use english	Documents that use other than english

Quality criteria

Articles that meet the requirements all criteria inclusion and exclusion in accordance with one of them criteria exclusion will reviewed fully for decide whether article the fulfil a series the criteria in question. In the review this, criteria quality made for netting articles that have been netted through criteria inclusion criteria quality focused on description use technology in learning and teaching materials discussed. The article validated in accordance criteria quality for evaluate clarity and relevance with objective research. Criteria quality served in form questions shown in Table 2. Each articles that will be analyzed must can answer all over questions on criteria items quality. If one of question no answered, then article no involved in review this.

Table 2. Quality criteria

No	*Quality criteria*
1	Whether article the describe use technology in learning with clear ?
2	Whether article the describe topic teaching materials with clear ?

Data analysis technique

Articles published between 2000 and june 2025 are criteria inclusion first, a total of 158 documents caught. Then based on type documents involved in review this is type conference paper documents and articles, where type conference paper documents are very useful for catch results initial and ongoing research taking place, which can become crucial for developing fields rapidly like technology and science computer (Scherer and Saldanha, 2019).The document article provide more methodology detailed, comprehensive data analysis, and extensive discussion, which is important

for understanding and synthesis deep in SLR Dhiman et al., (2023), from second type document the as many as 130 documents caught, then based on language used (english) 129 documents caught.

With using keywords searches that have been determined, then the total number of articles obtained is 158 articles. The articles this obtained from results search in the scopus database. Then done filtering article in accordance with criteria inclusion (Table 1). Selection articles that are done shown in Figure 1.

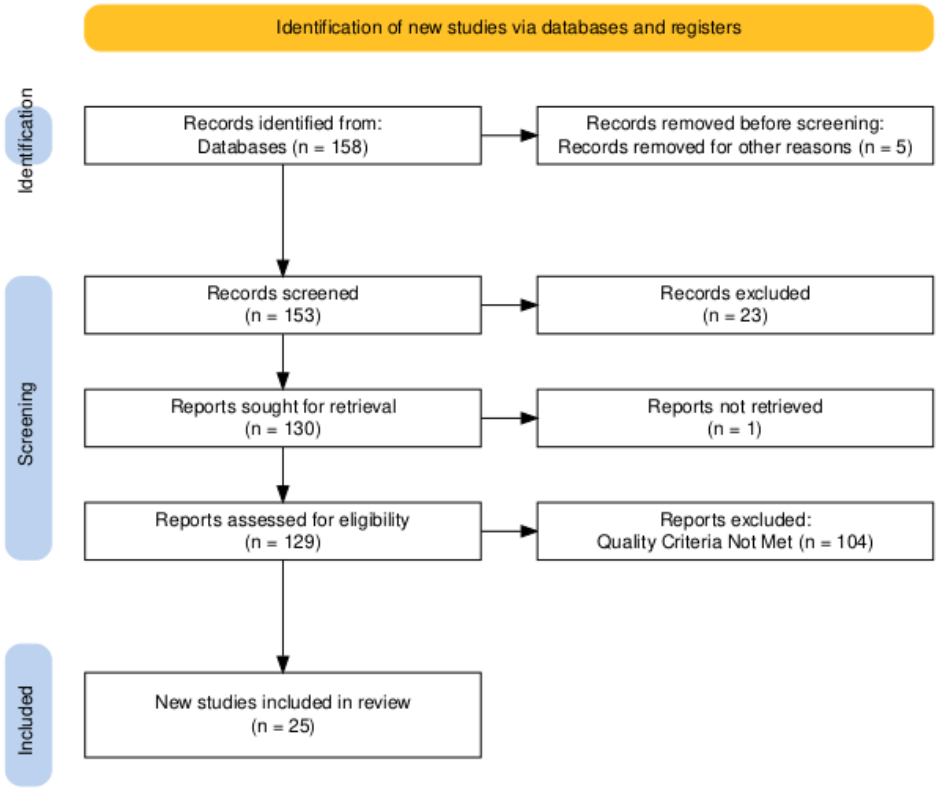

Fig 1: article selection using prisma method
(Haddaway et al., 2022)

Articles published between 2000 and june 2025 are criteria inclusion first, a total of 158 documents caught. Then based on type documents involved in review this is type conference paper documents and articles, where type conference paper documents are very useful for catch results initial and ongoing research taking place, which can become crucial for developing fields rapidly like technology and science computer Scherer and Saldanha, (2019). In addition, the document article provide more methodology detailed, comprehensive data analysis, and extensive discussion, which is important for understanding and synthesis deep in SLR Dhiman et al.,(2023), from second type document the as many as 130 documents caught, then based on language used (english) 129 documents caught.

After through stage screening in accordance with criteria inclusion said, 129 articles stated fulfil condition the beginning of this systematic literature review . However, articles the still through stage selection that is selection end for see whether criteria quality (Table 2) required for each article already fulfilled or not yet. Selection end involving 129 publications included in a systematic literature review. A total of 25 articles fulfil research data requirements, which include description use technology in learning as well as draft HEV technology in teaching materials discussed.

Result and Discussion

Discussion done with analyzed 25 articles that met research data requirements for know trend development Hybrid Electric Vehicle fundamental teaching materials in vocational education, integration digital technology that can used by teachers in do effective learning for teach HEV technology in vocational education, as well as draft what only those who often discussed and which concepts are still need and become priority for developed in vocational education.

Result

Hev teaching material development trends

Based on results searches that have been done through a series the selection is set, then results recapitulation article about development HEV teaching materials in vocational education obtained can seen in Table 3.

Table 3. Recapitulation of systematic literature review articles

No	*Authors*	*Title*	*Year*
1	(Das, 2024)	Developing a course on electric vehicles modeling for mechanical engineers: challenges and experiences	2024
2	(Saleet et al., 2023)	Importance and barriers of establishing educational/training programs in electric vehicles/hybrid electric vehicles in jordan	2023
|	|	|	|
|	|	|	|
24	(G. Liao et al., 2007)	Implementing an integrated learning environment for hybrid electric vehicle technology	2007
25	(G. Y. Liao et al., 2007)	Multidisciplinary learning materials for hybrid electric vehicle technology	2007

Amount published articles each the year (Figure 2) shows happen improvement in development HEV teaching materials. Although amount article limited from year to year as well as existence fluctuations amount article each the year, but in a way overall happen improvement.

Amount most articles published occurred in 2012 with amount article as many as 4 documents, which show that strong interest in study learning hybrid electric vehicle technology occurred in the years this along with start popularity the use of hybrid electric vehicles in various countries, which is influenced by the transition going to efficiency energy and reduction emission carbon (Aimo Boot & Consano, 2008). Figure 2 explain number of articles per year.

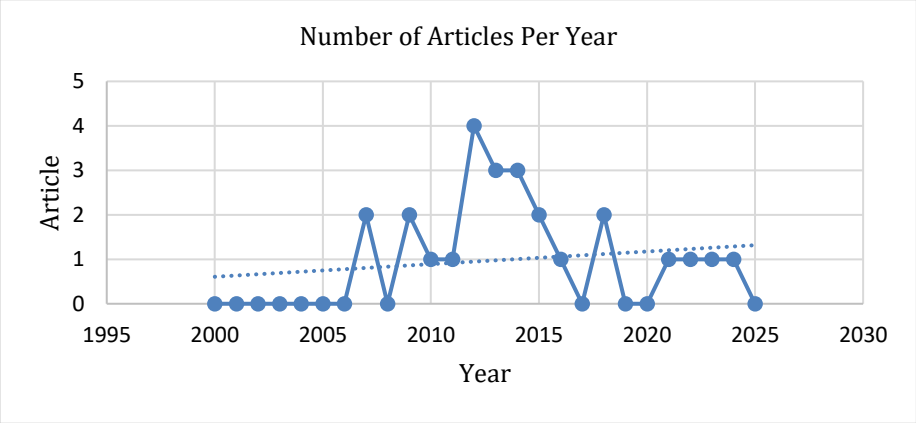

Fig 2: number of articles per year

Improvement this associated with height request will competence student in do maintenance and repair hybrid vehicles in the industry global automotive. We can look trend publication HEV teaching materials based on distribution geographically in Table 4.

Table 4. Publication trends in HEV teaching materials

Year	*Number of publications*	*Published in*	*Geographical distribution*
2024	1	Asme international mechanical engineering congress and exposition, proceedings (imece)	United states
2023	1	World electric vehicle journal	Jordan
|	|	|	|
|	|	|	|
2009	2	41st north american power symposium	United states
		Icemi 2009 - proceedings of the 9th international conference on electronic measurement and instruments	
2007	2	Asee annual conference and exposition, conference proceedings	United states
		Volume 7: engineering education and professional development	

In a way geographical, majority studies originate from developed countries in a way technology such as the United States (64%) and several European countries such as the United Kingdom, Spain,

Slovenia, Austria, Netherlands (28%), while in asia it was recorded only China and Jordan (8%) have follow contribute to development HEV technology teaching materials. meanwhile in Africa, Southeast Asia and the region develop other not yet there is contribution. In case level education, some big studies target education tall vocational or applied, with focus limited to vocational High School.

Technology and Learning Media Used

Integration of HEV technology into in curriculum vocational education is need urgent, remembering rapid growth industry automotive focused on vehicles friendly environment Fajri et al., (2016). This is push institution education for adapt and update curriculum them so that learning the more effective so that competence student can in accordance with development industry, including integrate digital technology in HEV learning. Based on results review included articles, obtained digital technology used in HEV learning in education vocational. Recapitulation results implementation digital technology is shown in Table 5.

Table 5. Digital technologies used in hev teaching materials

Digital technology	*Number of articles*	*Percentage of studies*	*Example tools/platforms*	*Main learning objectives*
Virtual laboratories & experimental platforms	6,7,8,9,10, 12,16,17,1 8,19,20,22	48%	Lab test bench, gearset modeling tools, power-split prototype	Practice , experimentation , and application control as well as hev architecture
Interactive multimedia & simulation-based learning	1,3,5,13,1 4,15,23	28%	Matlab/simulin, simulation software	Explore the complex concept of HEV through interactive simulations
E-learning & digital curriculum systems	2,4,11,21, 24,25	24%	E-learning & lab integration, e-learning & physical setup	Management digital learning and integration HEV curriculum

Recapitulation results analysis the most frequently used digital technology integrated in development HEV teaching materials include 12 articles (44%) on virtual laboratories & experimental platforms, category this covers technology based virtual laboratories as well as physical used for experiment practical and testing hev system digitally. The goal is for give experience hands-on without limitations space and time, according to characteristics education vocational. Examples of tools: lab test bench, educational HEV kit, web-based lab, portable lab unit, cad tools, PHEV prototype. Category furthermore namely interactive multimedia & simulation-based learning with 7 articles (28%), category this covers technology used for visualization

interactive, modeling systems and simulations dynamic in learning HEV concept. The main objective is to deepen the conceptual understanding of hybrid systems through digital representations that approximate real conditions. Examples of tools: matlab/simulink, sysml, simulation software, HEV energy simulation tools. And the last category is e-learning & digital curriculum system with 6 articles (24%), this category focuses on technologies that support digital learning management, online curriculum integration, and cross-disciplinary collaboration. This technology allows learners to access hev materials anytime and anywhere, and supports synchronous and asynchronous learning. Examples of tools: LMS, e-learning modules, digital course materials, blended learning platforms.

Frequently Used HEV Concepts Entered

Various concepts and topics discussed in literature also shows diversity in HEV education. Based on review results from included articles, obtained fundamental concepts that are often discussed in HEV learning in vocational education. Recapitulation results the fundamental concept of HEV is shown in Table 6.

Table 6. fundamental concept of HEV

Category draft	*Number of articles*	*Percentage of studies*	*Main sub concepts*	*Main learning focus*
Powertrain architecture & configuration	6,7,8,9,22, 23,	24%	1) Series, parallel, series-parallel HEV 2) Plug-in hev (PHEV) 3) Range extender HEV	Understand difference architecture and flow energy in various HEV type .
Energy storage & conversion systems	11,	4%	1) Battery (li-ion, nimh) 2) Ultracapacitor 3) Fuel cell integration 4) Charging & discharging mechanism	Analyze the performance of batteries and energy storage systems in the hev operating cycle.

Based on results analysis (table 6) found that part big study focuses on powertrain architecture and configuration as well as management strategies energy. Second draft this become base main in development HEV teaching materials because related direct with method work system hybrid and setup flow energy within vehicles. In addition, many the research also discusses modeling and simulation system, which is used for help understand performance vehicle as well as designing system more control efficient. Study of dynamics and performance vehicles also appear enough often, especially related analysis drivetrain mechanics and efficiency energy. Another concept that is quite lots discussed is system electricity and electronics power, which is related with electric motor control and integration system mechanical-electrical. Some the article also highlights storage and conversion energy, as well as aspect safety, standards and readiness power work in context Hybrid Electric Vehicle. In general, results this show that study about HEV more lots directed at understanding structure system driver, management energy, and application simulation system as base learning in the field vocational education.

Discussion

Literature show that development teaching materials for Hybrid Electric Vehicles (HEV) have been shift from delivery based studying conventional going to design pedagogical based simulations, projects, and laboratories. Most of reviewed studies emphasize understanding system practical through arrangement experiment direct such as, testbeds, benchtop rigs, scale HEV prototypes small and environment learning based modeling like matlab/simulink (Constans, Acosta, et al., 2014; Diaz-Diaz et al., 2018; Fajri et al., 2016; Steffen et al., 2022). In development stage beginning, material HEV learning especially focus on dynamics vehicle and powertrain modeling, such as "developing course modeling electric vehicles for engineer mechanics" Chen et al., (2013) which reflects domination aspect theoretical and analytical. However, more detailed research is new, such as "learning based project for hybrid powertrain control using simulation models" Steffen et al., (2022) and "development small-scale HEV setup for education" Fajri et al., (2016) show shift to direction approach experiential and multidisciplinary, which integrates principles system mechanical, electrical, and control. Significant trends are also visible in study oriented curriculum, in particular in development of integrated programs that are aligned with demands industrial electrification, such as the "education program for electrification transportation" Emadi and Ehsani, (2010). Studies this highlight urgency equip participant educate vocational with competence mobility green, which bridges gap between awareness sustainability and skills technically. In terms

of overall, this global trend reflect shift paradigm from learning based knowledge to learning based competencies and systems, which emphasize integration contextual, practice live, and digital.

Throughout reviewed studies, dominant digital technology used for increase interactivity, accuracy simulation, and accessibility HEV learning . The most frequently used technology adopted includes matlab/simulink, virtual laboratories , software simulation interactive , and computer assisted learning platform (CAL). Device simulation like, matlab/simulink dominates because allows student visualize flow energy dynamic, management strategy power and response system real time control. For example, research about "system learning assisted computer for HEV control platform" Zhang and Zhang, (2021) and "simulation interactive for teaching power management" Stojcic et al., (2013) show how technology this bridge gap between theory control abstract and real -world applications. While that, virtual and distance laboratories far away, like in "electric car drivetrain: development virtual laboratory for electronic learning" Prasanth et al., (2012) and devices 3D printing, such as in "Devices 3D printed power splitter for testing energy" Torres et al., (2015) reflect effort for make more HEV experiments flexible, easy accessible and economical cost. These technologies differ primarily in the level of immersion and interactivity:

1) Virtual laboratories & experimental platforms, for give experience hands-on without limitations space and time, according to characteristics education vocational.
2) Interactive multimedia & simulation-based learning, deepens conceptual understanding of hybrid systems through digital representations that approximate real-world conditions.
3) Digital curriculum system, focusing on supporting technology management digital learning, integration online curriculum, and collaboration cross discipline.

The integration of digital technology contribute to the ecosystem learning hybrid in HEV education ecosystem that combines precision digital modeling with authenticity task engineering directly. Synergy this in harmony with demands environment training automotive driven by industry 4.0.

Synthesis from 25 studies show that HEV teaching materials in general consistent emphasize several core technical and conceptual domains, namely:

1) Powertrain architecture & configuration (24%)
2) Energy management & control strategies (16%)
3) Vehicle dynamics & performance (16%)
4) System modeling & simulation (16%)
5) Electric machines & power electronics (12%)

6) Safety, standards, and maintenance (12%)
7) Energy storage & conversion systems (4%)

These concepts are pedagogically integrated through various learning models. The dominant approach is Project-Based Learning (PBL), in which learners design, simulate, and implement a hybrid powertrain or prototype system. PBL not only enhances technical understanding but also fosters creativity and teamwork, essential attributes in modern vocational contexts. Simulation-based learning is the second most common strategy, allowing students to explore control algorithms and energy efficiency strategies in a risk-free virtual environment. Studies such as "Teaching power management engineering through interactive simulation" Stojcic et al., (2013) clearly illustrate how simulation based environments enhance conceptual retention and reduce cognitive load when dealing with complex HEV systems. Laboratory and prototype based pedagogies, for example, "a hybrid electric "green mobility" laboratory and development of a small-scale HEV setup for education" Thompson et al., (2011), serve as experiential platforms that translate theoretical models into practical understanding. Meanwhile, multidisciplinary approaches and systems engineering such as, "using systems engineering principles to improve learning outcomes" Asher et al., (2018) push understanding holistic about HEV technology with connecting the mechanical, electrical, and control domains. Finally, learning oriented sustainability, although more rarely, adding dimensions important contextual, connecting HEV education with more issues wide about energy clean and responsible answer environment. Balance between mastery technical and awareness contextual this mark evolution significant in how HEV basics are taught in vocational education. Reviewed studies highlight that effective HEV teaching materials blend digital simulation, experiment practical, and contextual project authentic. Digital technology does not functioning as standing tool alone, but rather as a mediator who translates knowledge technical abstract become understanding applied. In pedagogical, PBL, learning based laboratory and learning based simulation appear as the most effective strategy for develop competence cognitive and procedural. In the context of education vocational, synthesis this confirm that HEV curriculum in the future must enriched digitally, multidisciplinary, and competency oriented, as well as integrate perspective modeling, manufacturing prototypes, and sustainability. The integration ensure that participant educate no only speak in a way technical but also adaptive to landscape technology vehicle electric and hybrid developments rapidly.

Conclusion

Review library systematic this reviewed 25 studies international about design and development Hybrid Electric Vehicle (HEV) teaching materials in education vocational and technical analysis this guided by three question research that discusses trend development material, role digital technology, and focus conceptual pedagogical source power learning HEV related findings this show consistent global trends going to integrated HEV education, supported digitally, and based competency. Initial HEV learning design emphasize modeling analytical and explanatory theoretical about dynamics vehicles and systems driving force. Over time, the approach this develop become environment study based project, which was refined with simulation, and laboratory centered, which allows participant educate for experience complexity HEV system through tasks live and interactive.

Digital technologies, particularly matlab/simulink, virtual laboratories, interactive simulations, and computer assisted learning systems, have emerged as key drivers of this transformation. These tools bridge conceptual understanding and practical experimentation, enabling students to visualize power flows, optimize control strategies, and test hybrid configurations in both physical and virtual environments. The variety of technology use suggests that effective hev learning design depends on the desired depth of engagement: modeling and analysis for conceptual mastery, simulation for exploration, and prototyping for applied competency.

This review further identifies key conceptual domains that frequently shape HEV teaching materials: vehicle dynamics and powertrain modeling, energy management and control strategies, powertrain architecture, model based and embedded control, multidisciplinary system integration, and sustainability awareness. These concepts are most effectively delivered through Project Based Learning (PBL), simulation based learning, and laboratory based experiential pedagogies, each of which fosters distinct but complementary conceptual, procedural, and contextual aspects of vocational competencies. From a pedagogical perspective, this synthesis underscores that effective HEV education requires the integration of technical knowledge, digital literacy, and sustainability values. Teaching materials should evolve beyond content transmission to authentic design experiences, where students engage in problem solving and experimentation that mirror real world hybrid vehicle systems. This aligns well with the mandate of vocational education to produce graduates who are not only knowledgeable but also industry ready and adaptable.

For educators and curriculum designers, this review suggests that HEV instructional materials should incorporate multi platform digital technologies (e.g., simulations, virtual laboratories,

prototyping devices) to support a hybrid learning ecosystem. Embedding integration multidisciplinary across the mechanical, electrical, and control domains, reflecting practice industry real. Adopt pedagogy based project and based driving issues thinking design applied, experimental, and collaborative. Includes theme sustainability and mobility green for contextualize learning technical in objective transition global energy.

Study upcoming must expanded to direction approach study knowledge design for in a way systematic develop and evaluate prototype customized HEV learning for context vocational. Research can also explore analytic performance learners in environment based simulation, augmented reality/virtual reality integration for immersive HEV training, and framework work collaboration cross institutions that connect schools, universities and partners industry in education vehicle hybrid. In short, HEV education is being move towards an era of supported learning digitally , practice oriented , and data based sustainability. Through integration strategic technology, pedagogy, and knowledge multidisciplinary, institution vocational can prepare generation technicians and engineers ready contribute to transformation global mobility is currently ongoing.

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