Development and Practice of Textbooks for Vocational Undergraduate Programs under the Backward Design Path: Taking New Energy Vehicle Power Battery Management Technologyas an Example

Yiying Wang
Chongqing Polytechnic University of Electronic Technology, Chongqing, China

Abstract: The subject of the course New Energy Vehicle Power Battery Management Technology is the main one in the field of Intelligent Connected Vehicle Engineering Technology. It was however that the creation of its learning materials has been a problem with regards to the homogenization of applied undergraduate textbooks and the differences between the thickness of the textbooks of vocational diploma and those of the applied undergraduate books, which created an indistinct type positioning. This research is based on the backward design approach (i.e., industry chains - job positions - vocational competencies) as well as the field work of power battery and vehicle manufacturing companies in Chongqing, where it focuses on the difference in the demands of the three levels of education, namely vocational undergraduate, applied undergraduate, and vocational diploma. The study explains the minimal degree of higher education features and the maximal level of vocational features in this particular course. In turn, five-project content system and five-stage competency matrix were developed. To determine the content and the work orders, a two-dimensional task frequency importance matrix was established through Position Task Analysis method. The results show that the development of the textbook can be considered as a verifiable process of type setting and the reusability of the procedure of developing the vocational undergraduate textbook.

Keywords: Vocational Undergraduate Education; Power Battery Management Technology; Backward Design; Job Position Differential Analysis; New-format Textbooks

1. Introduction

New energy vehicles are the strategic move in the process of China becoming a global power of automotive industry as opposed to a large producer of cars. It is a key policy towards achieving the goals of the Dual Carbon, that is, carbon peaking and carbon neutrality, and the formation of new productive forces of quality (new high-quality productive forces).As the Outline of Constructing a Strong Education Nation(2024-2035) continues to be implemented, the vocational undergraduate education which is one of the most important sources of the creation of highly skilled technical professionals will continue to develop into the so-called connotation construction (internal quality development) with its five main elements, namely, specialties, curricula, faculty, and internship training. The text focuses on enhancing the mechanism of organization of the textbook production and building, diversification of textbooks forms, filling the gap between the national planning textbooks of the areas where there is a shortage, including advanced manufacturing [1].

The development of new energy textbooks to be used by majors in vocational undergraduate schools is not yet able to match what industry requires at the moment. Due to this gap, most of these schools have to use books that were initially developed to be used in applied undergraduate programs, which makes it unclear what kind of program it is [2]. When math foundations are already cut short and practical training hours are limited, using these wrong textbooks causes two big problems at the same time: students don't get enough deep theoretical knowledge, and they also don't get to build up strong practical skills [3]. To fix this issue, vocational undergraduate textbooks need to get out from under the limits of traditional disciplinary logic, and switch to a logic that follows actual work processes. Even so, there are still very few clear working ways to successfully combine “higher education attributes” and “vocational attributes” together in specific majors right now.

The New Energy Vehicle Power Battery Management Technology is a primary course of the Intelligent Connected Vehicle Engineering Technology students. The subject of the course is divided into four aspects, namely, electrochemistry, high-voltage safety, electronic control and data communication which will directly influence the performance of the entire vehicle in terms of the baseline of its safety as well as driving range. This paper discusses the general issues that are usually present in the textbooks currently used such as they do not update their contents to align with changes in the national standards (such as GB 38031), too much emphasis on theoretical derivation and lack of practical work order decision making, and also how it does not relate to the working conditions in enterprises. To perform this work, the study was conducted under a special project that received financial support by the National Steering Committee of Automotive Vocational Education.

The study has been designed in the reverse direction and the sequence of it is as follows: Industry Chain - Vocational Competencies - Technical Fields - Curriculum System. It makes a specific assessment on the job demand in vocational undergraduate, applied undergraduate and vocational diploma education. By means of this, we will be able to determine what capability thresholds are required by the vocational undergraduates. We then created a textbook of new style that includes the project leadership, task-oriented modules, work manuals, and digital empowerment. The primary purpose of such a textbook would be to provide an example of how others can emulate it so as to address the issue of excessive similarity among the existing textbooks in vocational undergraduate programs.

2. Problems in Current Vocational Undergraduate New-Format Textbooks

2.1 The Misalignment between Industrial Iteration and Talent Specifications

The majority of the current debates on the new format vocational undergraduate books are concentrated in the questions which are superficial, such as the one about whether to use loose-leaf pages or even to add a QR code. It is not that they disagree with each other, but it is that there is a mismatch between the rate at which industrial technology is changing and the rate at which the textbooks are updated. This issue can be particularly poor in the case of engineering disciplines.

The old traditional books on content are also characterized by the fact that they have something like a disciplinary inertia, which is to say, the knowledge is arranged in accordance with the degree of completeness of the subject itself and not the needs of the workplace as such. The principles-structures-calculation chain remains intact, although it lacks the modular design, realistic context and digital linkages, required by the learning process based on work. Due to this, there will be no time to introduce new standards of industry, employment and the newest technologies into the classroom.

In the case of fast moving fields, such as Intelligent Connected Vehicle (ICV) Technology, it does not have any partial revision process on course content. It is a dangerous situation that the textbook will be outdated in its standards and the workshop will be based on the new working logic. This discrepancy makes graduates less prepared to the actual technical requirements which the industry demands [4].

The course New Energy Vehicle Power Battery Management Technology is in fact far more complicated than most other courses, and to add insult to injury the industrial update cycle is becoming ever quicker. Currently, there are three distinct mismatches (the mismatch in iteration speed, the mismatch in content complexity, and the mismatch in course positioning) that combined make it much more difficult to produce good vocational undergraduate textbooks on this topic.

Iterative misalignment occurs due to the fact that national standards (which are GB standards) and industry rules are continuously changing on matters such as insulation detection, voltage difference control, thermal runaway warning, BMS functional safety, and even fault tolerance. Once textbooks are completed in the conventional publishing processes, they will always lag behind the new developments. This manifests itself in terms of outdated safety standards, oversimplified strategies and superficial fault tree analyses.

The complexity misalignment is primarily concerned with the amount of competency that is required. The students majoring in vocational subjects at the undergraduate level require the skills of making diagnostic decisions based on data streams and thresholds. In order to develop this skill, books are required to extract the most important factors of decision-making in the industry, and then create chains of training which will be implemented by means of a textbook, which will lead to the actual working process. This does not mean that it would simply be providing little pieces of advice.

The misalignment of position is an indication that the textbooks on vocational and applied undergraduate are quite alike to each other. In case of borrowing textbooks by the programs, which are too theory-based, students will be in a position to recite the most fundamental concepts, yet they are unable to create their own plans of maintenance according to the way the companies order and arrange work. Conversely, where only the higher level vocational texts are used by the programs, students can easily disassemble and replace damaged components but lack sufficient skills in determining the cause and effect of all the systems and choosing the best solution to a problem [5].

2.2 Blurred Typological Positioning of Vocational Undergraduate Textbooks

The most pressing issue is the fact that nobody has ever defined what a vocational undergraduate textbook should be. In other words, it is still difficult to say what logic of work such books must comply with, how many pages they need to contain, and whether they are required to be more practical in terms of training [6]. The present-day situation is that the two demands have been placed on the textbooks of vocational undergraduates at the same time: one demand is to maintain the entire knowledge framework of an ordinary undergraduate education, and another demand is to meet the requirements of the vocational education system. Many special courses will find themselves in a position where there is no clear cut between the characteristics of higher education and the features of vocational training.

As an illustration, most of the existing vocational undergraduate studies are based on the books that were initially prepared in the applied undergraduate studies. The lack of sufficient teaching resources with definite vocational elements means that the majority of the content has to be borrowed from the conventional undergraduate teaching materials. Authors of these textbooks do not have much information about what is happening in the real job positions and thus it is quite difficult to explain how the so-called vocational attributes can be manifested in the curriculum. At this moment, there are no boundaries as to where the practical work should end. Due to this, the entire process of working becomes reduced to the bare bones of the work, operational steps. This makes the meaning of the term vocational attributes empty and they are only words which are added over the other material instead of the content itself [7].

This ambiguity of the typological positioning is mainly due to the fact that the researchers have not been able to separate the job task levels in three types of education, which are vocational diploma, vocational undergraduate and applied undergraduate. To elaborate further, the majority of the vocational diplomas are aligned with the implementation level and they are more oriented towards the development of the skills in operations. The applied undergraduates are positioned at the design level and their emphasis is on the modeling of theory as well as research and development. The middle ground between the two is the diagnostic decision-making layer, which has to be filled by the vocational undergraduate programs. This is precisely why this paper has taken the backward approach to industry chain, job positions and vocational competencies. In the process of making a comparative analysis of the demands of jobs in the three educational levels, this paper desires to establish some content limits that will be applicable only in the vocational undergraduate education.

3. Breakthrough Pathways for Vocational Undergraduate Textbook Development

3.1 Theoretical Anchoring of the “Backward Design Path”

The problem of the structural issues in the field of industrial updating and talent requirements as well as the lack of clarity on the type positioning are addressed by this study which is not based on the conventional approach of subject-discipline-based forward design. It instead follows the backward design path as its core theory of reference. The first one to propose this theory was Wiggins and McTighe, who wish to address the issue of teaching objectives and testing. It emphasizes that you should consider the end product first, implying that the teaching design is designed according to the expected outcome [8]. In the sphere of vocational education, Xu Jianling has already made it a definite step-by-step reasoning process: Industry Chain - Job Positions - Vocational Competencies - Technical Fields - Curriculum System. This is a direct theoretical foundation of this research paper.

When we break down how the backward design path works, it has three main core parts:

The former is Input Anchoring: we shift the location of where the authority lies, not only to be based on editor experience but also actual demands by the industrial chain. As an example, this paper considers the entire power battery industry chain, i.e., material and cell making in the upstream, PACK integration and BMS in the midstream, vehicle assembly and cascaded after-sales use in the downstream as the sole source of textbook materials. This ensures that the vocational characteristics of the entire development process remain aligned with what the industry actually requires.

Second, The logic change: the enumeration of knowledge to the mapping of competencies [9]. In the case that we are in the Position Task Analysis (PTA) process, it is what the industry chain as a whole requires that becomes work competence points which can be perceived and quantified by the people.

Third, Output Closure: Changing the knowledge indoctrination to deliverable evaluation [10]. At this stage, content of textbooks is matched directly with job performance metrics. The model employs a feedback loop that runs as follows platform data collection teacher diagnosis and improvement textbook revision which ensures that teaching materials are always in a state of dynamic and repeated updating and closure.

3.2 Survey Design and Empirical Findings on Job Content Differences across Three Educational Tiers

Table 1. Distribution of Survey Samples

Enterprise Type	Questionnaires Distributed	Valid Questionnaires Returned	Effective Response Rate	In-depth Interviews Conducted
Cell Manufacturing Enterprises	50	42	84%	5
PACK Integration Enterprises	50	41	82%	5
Vehicle Manufacturing Enterprises	50	45	90%	6
After-sales Service Centers	50	40	80%	4
Total	200	168	84%	20

Table 2. Comparative Analysis of Job Task Characteristics across Three Educational Tiers

Dimension	Vocational Diploma (Execution Layer)	Vocational Undergraduate (Diagnostic Decision-Making Layer)	Applied Undergraduate (Design Layer)
Core Focus	Operational Standards, Tool Usage, Process Execution	Fault Mechanisms, Data Interpretation, Strategy Selection	Material Mechanisms, Mathematical Models, Code Programming
Typical Task Examples	Module Replacement, Insulation Value Detection, Bolt Fastening	Root Cause Analysis, Strategy Formulation, Optimization of Management Parameters	BMS Architecture Design, Algorithm Development, Cell Formula Improvement
Task Complexity	Low: Single action, deterministic outcome	Medium: Multi-factor coupling, requires data-based causal inference	High: Requires building abstract models to solve unknown problems
Theoretical Depth Required	Proficient: Component identification, understanding parameter meanings	Comprehensive: Understanding circuit topology, communication protocols, control logic	Advanced: Mastery of electrochemical kinetics, derivation of control theory

Through one-way Analysis of Variance (ANOVA) and post-hoc multiple comparisons of the questionnaire data, combined with the coding analysis of the interview transcripts, this study clarifies the statistically significant differences in job task characteristics across the three educational tiers, as presented in Table 2.

This study aims at establishing definite positioning boundaries of vocational undergraduate textbooks, therefore we have employed a mixed research approach that combines the questionnaire surveys and semi-structured interviews to obtain more robust triangulated information.

The questionnaire of this research was divided into two parts: the general information of the enterprises and the enumeration of all their job tasks. Our sample was obtained from firms belonging to the power battery industrial cluster in Southwest China. Meanwhile, we conducted in-depth interviews with 20 key technical workers from 12 different representative firms. The distribution of valid samples over the group is shown in Table 1.

4. Case Study: Development of the New Energy Vehicle Power Battery Management Technology Textbook

4.1 Overall Architecture

Based on the “backward design path” idea and the different positions of the three education levels, this study builds a three-layer mapping structure for textbooks: “Industry Chain Demand Anchoring — Vocational Competency Mapping — Project Module”.

Main Framework: Cover All Parts of the Industry Chain. This textbook uses the five core parts of a power battery's whole life cycle as the starting point for its content. This makes sure that the teaching material it has stays connected to what actually happens in real industry work:

The upstream part: this covers making battery cells and checking how well they perform;

Midstream: PACK integration work, plus the assembly and testing of BMS (Battery Management System);

Downstream: full vehicle assembly, running and upkeep of charging infrastructure, after-sales problem checking, and second-stage reuse of old batteries.

Secondary Architecture: Differentiated Construction of the Competency Map. On the meso level, the textbook breaks down a five-part map of vocational skills. This map sets clear rules for where “higher education features” and “vocational features” overlap for vocational undergraduate students, which you can see in Table 3.

Table 3. Competency Map and Typological Positioning for the Vocational Undergraduate Textbook New Energy Vehicle Power Battery Management Technology

Competency Dimension	Core Competency Items (Vocational Undergraduate Exclusive)	Typological Positioning
BMS Architecture Cognition	Topology Analysis, Communication Protocol Interpretation, Hardware Interface Identification.	Lower Limit of Higher Education Attributes: Understands principles, rather than mere operation.
Data Interpretation & Analysis	CAN Message Parsing, Voltage Difference Trend Analysis, SOH/SOC Data Correlation.	Core of Vocational Attributes: Capable of diagnosis, rather than mere execution.
Strategic Decision-Making	Equalization Strategy Selection, Thermal Management Logic Optimization, Charging Parameter Matching.	Key Differentiation: Possesses decision-making capability, rather than mere design.
Safety & Compliance Operations	High-Voltage Power-Off Procedures, Insulation Testing Standards, National Standard (GB 38031) Implementation.	Safety Baseline: Adheres to the bottom line, exceeding vocational diploma standards.
Fault Tree Construction	Voltage Difference Fault Attribution, Thermal Runaway Warning Assessment, Maintenance Scheme Output.	Higher-Order Capability: Solves complex problems, rather than simple replacement.

Tertiary Architecture: The packaging of the modules in the project will be contextualized as follows. We have discussed a competency map above and it is divided into five consecutive projects with 18 similar tasks that can be used to achieve the overall goal. These projects are arranged in an easy-to-follow sequence, where each step is more difficult than the previous one, and so on, which is known as the Cognition – Manufacturing – Testing – Maintenance - Management. Every single project corresponds directly to the industry chain segments and skill groups in Table 4.

Table 4. Contextualized Packaging and Competency Mapping of Project Modules

Competency Stage	Corresponding Project	Core Technical Module	Key Competency Output (Vocational Undergraduate Exclusive)
Foundational Cognition	Project 1: Power Battery Cognition and Parameter Identification	• History and Industry Chain Analysis • Basic Parameter Identification • Data Stream Reading and Parsing	• Industry Chain Analysis Capability • Data Stream Interpretation Capability (Addresses the “lower limit of higher education attributes”: Understands the industry and interprets data.)

Manufacturing Process	Project 2: Power Battery Manufacturing and Assembly Process	• Cell Manufacturing and Lithium Electrochemistry • Module Production (CTP Technology) • PACK Assembly and Tool Specifications	• Derivation and Understanding of Electrochemical Equations • CTP Process Implementation Capability (Addresses the “depth of vocational attributes”: Understands mechanisms and refines craftsmanship.)
Testing & Validation	Project 3: Power Battery Testing and Verification Technology	• Safety Testing (GB 38031) • End-of-Line (EOL) Testing • High-Power Charge/Discharge Testing	• Execution of National Standard Test Procedures • Test Data Analysis and Report Writing (Addresses safety compliance requirements: Adheres to standards and performs analysis.)
System Maintenance	Project 4: Power Battery System Maintenance and Overhaul	• Battery Pack Disassembly and Air-tightness Testing • High-voltage Relay Replacement and Topology Analysis • IP67 Sealing Testing and Hardware Repair	• Understanding of Topological Structure Design • Hardware-level Fault Troubleshooting Capability (Addresses on-site diagnostic capability: Understands structure and can disassemble.)
Intelligent Management	Project 5: Power Battery BMS and Energy Management	• BMS Communication Protocols and CAN Bus • SOC/SOH Algorithm Verification • Thermal Management and Active Equalization Implementation	• CAN Bus Diagnostic Capability •Active Equalization Strategy Implementation Capability (Answers the core higher-order capability: Masters data and excels at decision-making.)

4.2 Reconstruction of Instructional Modules

The paper will develop the T-C-A-M model that operates in four phases: Task extraction, Complexity pruning, Assessment wrapping and Modular scaffolding. It is a 4 step process of transforming the way we teach. The idea behind this is to take the chaotic messiness of actual production processes used by companies and then put them into a form of modules that can be easily used in textbooks as an educational material. This allows us to draw a parallel between the reality of projects which are performed by companies and the modules which teachers can actually apply in their classroom. To demonstrate how it works, we have the chapter on Power Battery Energy Management. We will explain the transformation process in its four steps to make it easier to understand.

Step 1: Task Extraction.

Here we are faced with the fundamental question of where does the content of the textbook actually come from. Using the case study, Deepal Automobile Shared Vehicles Experiencing Sudden Winter Range Drop that is presented in the sample chapter, the team that assembles the textbook received original work orders directly into the maintenance database of the enterprise concerned. The particular regulation they applied was: select 50 cars which exhibit a voltage difference which attains 185 mV and require a maintenance plan to be completed and distributed within 24 hours. Such mode of working ensures that the content of the textbook has such vocational authenticity that people mention in vocational education.

Step 2: Complexity Pruning.

This part of the work provides an answer to the question: what exactly should the textbook teach. Considering the example chapter that we worked on, the development team eliminated electrochemical R&D information which is far too technical because this book is designed to be used by applied undergraduate students. We also removed very basic and repetitive steps of replacing parts which were initially targeted at vocational diploma students. What remains after this cutting is only the set of skills that students require: beginning with data analysis of voltage difference, then choosing the correct equalization strategy, and developing a complete maintenance plan. This ensures that the teaching material indeed matches what instruction requires, and we refer to it as instructional relevance.

Step 3: Assessment Wrapping.

This section addresses the issue of how to assess what is contained in the textbook content. As an illustration, when undertaking an equalization task, the textbook instructs students that they must record insulation resistance values and voltage difference thresholds directly on the physical pages of the book and also submit their analysis reports of the equalization curve online through a digital platform at the same time. This form of application of two distinct approaches simultaneously creates a closed loop of all process data and it effectively combines hands-on physical work with digital problem checking into one system.

Step 4: Modular Scaffolding.

This section examines the issue of how the content in the textbook becomes more complicated progressively. It establishes various degrees of difficulty on identical tasks. In case we consider equalization task as a good example:

Basic level: students have to perform routine equalization works by strictly adhering to SOP. It corresponds to what is expected from students in execution-oriented vocational diploma programs.

Advanced Layer: Students should investigate the fundamental causes of voltage variation, such as distinguishing between sampling drift and cell degradation. This corresponds to the diagnostic decision-making level that is characteristic of vocational undergraduate education.

Extension Layer: Students are requested to modify the equalization thresholds in a dynamic manner, depending on what the existing State of Health (SOH) is. This section of the work is aimed at developing higher-order innovative skills among students.

4.3 Design of the New-Format Ecosystem

The study is a three major change in the physical textbook medium and it creates a system of a new style that has three aspects, i.e. the work-based manual structure as its foundation, paper and digital interaction with it, and closed data cycle as its core.

The modern textbooks are not in the old format of a chapter-section narrative but rather it has been transformed to what is now referred to as work-manual style. The modern-day books have shifted their attention towards task work orders as the main unit of content, instead of trying to explain all knowledge points. Every particular assignment is based on five rigidly set structural elements: Safety Regulations - Operational Procedures - Data Recording - Delivery Standards - Evaluation and Sign-off. This transformation also implies that the students will be required to become something other than passive reader, i.e., an individual who does some work. This shift means that the role of the textbook is also altered; they no longer exist as reading material, but an operational guide which reflects the working conditions faced by actual enterprise engineers day after day.

The paper constructs a closed-loop task chain that adheres to the three steps: Paper-Based Standardization Digital Practical Training Platform-Based Traceability. Paper Terminal (Standardization): This section is responsible in determining hard constraints, such as task objectives, safety baseline regulations (such as the GB 38031 insulation standards), particular data points that require collection (such as voltage difference thresholds, SOH values), and formatting of final deliverables. Digital Terminal (Practical Training): It functions as a training space which allows users access using QR codes. These links connect to micro-mechanism animations, VR simulations of high-risk work processes (e.g., battery immersion testing) and diagnostic environments which collaborate with BMS data streams. Integration Logic: Both terminals focus on the same activity, i.e. Power Battery Equalization Operations. Each individual data entry box on the physical work order corresponds to one specific entry point of training within the digital environment. This ensures that the guidelines we employ to evaluate performance are aligned perfectly with the practice of students in their skills.

The present research has incorporated an updating mechanism of the following form, i.e. Platform Data Collection - Diagnostic Feedback - Textbook Iteration that enables the revision process to be dynamic in its nature and evolve with time. The platform will be collecting data as students are working on the project, it will document the steps they are taking and the frequency of the mistakes they make in the work such as Equalization Strategy Selection. Concurrently, there is a self-generated error heatmap made by the system. It also facilitates the teacher to identify the ambiguous sections in the textbook so that the diagnosis and feedback can be provided easily. As soon as the level of errors in one particular task exceeds our pre-defined value, or as industrial requirements are changed, the partial substitution of the loose-leaf modules will immediately be initiated. This allows the textbook to be revised and updated.

5. Conclusion

In order to address the real life issues of “blurred typological positioning” and “the deskilling effect caused by mixing paper and digital content" in the new-format textbooks on vocational undergraduate programs, this study uses the development of the New Energy Vehicle Power Battery Management Technology textbook as an example and develops a new textbook development model based on backward design. After explaining the special position of vocational undergraduate students - they work at the diagnostic decision-making layer, which is between the design layer and execution layer - this research creates a three-level mapping framework that links industry chain, competencies and projects. We apply the T-C-A-M teaching transformation model to transform real company work orders into task modules that can be taught and also assessed in class. This approach basically resolves the structural conflict between what textbooks cover and what jobs actually require.

When you consider practical application, this research does not merely add a layer of digital features to the conventional textbooks, which simply implies that QR codes are added to physical paper pages. Rather, it constructs a three-level ecosystem change based on the concept of work-manual standardization, digital resource training and data-driven iterative renewal. This model provides a reusable template of typological positioning in textbooks used in engineering-based vocational undergraduate courses. The most notable fact is that such national standards as GB 38031 are introduced directly into the design of task work orders. Such an approach assists the on-site engineers to have a better feeling about adhering to safety rules and also improves their capacity to make strategic decisions. Simultaneously, it offers a working reference direction on how to perform formal innovation to specialized textbooks in vocational undergraduate education.

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