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Glaserian Classic Grounded Theory in Practice: A Methodological Tutorial with an Empirical Illustration from Inventor-Entrepreneurs

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ABSTRACT

Purpose: This study aimed to clarify the distinctive methodological logic and decision-making processes of Glaserian classic grounded theory and to demonstrate their practical implementation through a worked empirical illustration involving inventor-entrepreneurs in engineering and technological education.

Methods and Materials: This qualitative methodological study was designed as a methodological tutorial rather than a systematic or scoping review. Methodological materials were purposively selected from foundational and contemporary literature on classic grounded theory and related qualitative approaches. The empirical illustration was reconstructed from a previous classic grounded theory study involving 10 entrepreneurial inventors, technology developers, innovative engineers, and owners of knowledge-based companies in electrical engineering, electronics, and computer engineering. Data sources included 60–90-minute in-depth semi-structured interviews, detailed field notes, expanded post-interview notes, analytical memos, and relevant documents. Analysis followed Glaserian procedures involving open coding, constant comparison, memo writing, emergence of the main concern, selective coding, theoretical sampling, theoretical saturation, and theoretical coding.

Findings: The analysis generated 367 initial codes and 70 main and subsidiary codes. Constant comparison showed that codes concerning theoretical dominance, university–industry separation, inadequate practical experience, and weak real-world problem solving converged around the main concern of insufficient attention to technological literacy in engineering education. Selective coding and theoretically directed comparison subsequently identified creative thinking, problem solving, teamwork, industrial experience, managerial capability, and economic capability as conceptually relevant to resolving this concern. These categories were integrated through the core category of injecting technological literacy into engineering education.

Conclusion: Methodological coherence in Glaserian classic grounded theory depends on maintaining an emergence-oriented analytical logic in which the main concern, core category, theoretical sampling decisions, and final theoretical relationships are progressively developed from data rather than imposed through predetermined frameworks.

Keywords: *Classic grounded theory; Glaserian grounded theory; methodological tutorial; main concern; core category; theoretical sampling; theoretical coding; engineering education; inventor-entrepreneurs; technological literacy.*

1. Introduction

Grounded theory has become one of the most influential qualitative methodologies for developing conceptual explanations of social processes directly from systematically analyzed empirical data. Since its original formulation, grounded theory has been distinguished from qualitative approaches whose primary purpose is description, interpretation, or thematic organization because its central methodological commitment is the generation of theory through an iterative relationship among data collection, coding, constant comparison, memo writing, sampling, and conceptual integration. In its original formulation, grounded theory was introduced as a means of allowing theoretical categories to emerge from empirical materials rather than requiring researchers to begin with hypotheses or explanatory schemes derived from existing theories (Glaser & Strauss, 1967). This principle fundamentally altered the relationship between empirical inquiry and theory generation by positioning theory as an outcome of sustained conceptual engagement with data rather than merely as a framework applied before data collection. Subsequent developments in grounded theory have expanded its use across education, health sciences, psychology, organizational studies, and other disciplines, yet they have also produced distinct methodological traditions with different epistemological assumptions, coding procedures, analytical priorities, and criteria for theoretical integration (Cullen & Brennan, 2021; Rieger, 2019).

Within this broader methodological family, Glaserian classic grounded theory maintains a particularly strong commitment to the principle of emergence. The researcher enters a substantive area of interest without predetermining the main concern of participants, the core category, or the final theoretical structure. Open coding is used to fracture the data conceptually, while constant comparison allows incidents to be compared with other incidents, codes with codes, and developing categories with additional data. Through this process, the researcher seeks to discover what is actually occurring within the substantive area and, more specifically, what problem or concern is repeatedly important to participants and how they continually attempt to resolve, manage, or reduce it (Glaser, 1978). The classic approach therefore does not treat coding as a purely classificatory procedure. Rather, coding initiates a progressively more abstract analytical process in which concepts are generated, compared, delimited, related, and ultimately integrated into a parsimonious conceptual explanation of the underlying social process (Holton & Walsh, 2017).

A defining feature of classic grounded theory is the distinction between emergence and forcing. Glaser argued that researchers should avoid imposing preconceived categories, coding paradigms, theoretical schemes, or disciplinary expectations on the data because such structures may obscure processes that participants themselves are actively experiencing (Glaser, 1992). In this view, theoretical sensitivity is developed through disciplined comparison, memo writing, conceptual openness, and engagement with emerging patterns rather than through the premature application of external theoretical frameworks. The issue is not that researchers approach data without knowledge, experience, or prior assumptions, but that they must resist allowing such assumptions to predetermine what counts as analytically important. The distinction between allowing theory to emerge and forcing data into existing conceptual frameworks is therefore not a minor procedural preference; it is central to the methodological identity of classic grounded theory (Sagharvani et al., 2014). This emphasis also explains why the timing and function of literature use, sampling decisions, and coding procedures are treated differently in the Glaserian tradition from some other qualitative approaches.

The development of grounded theory after its original formulation, however, resulted in substantial methodological diversification. The Strauss–Corbin tradition introduced a more systematic and procedural approach to category development, including explicit attention to relationships among conditions, context, action or interaction strategies, and consequences (Strauss & Corbin, 1998). Later refinements of this approach continued to provide researchers with structured procedures for developing categories, identifying their properties and dimensions, and integrating them into an explanatory model (Corbin & Strauss, 2015). Charmaz subsequently developed constructivist grounded theory, placing greater emphasis on the situated, interpretive, and co-constructed character of qualitative knowledge and explicitly foregrounding the role of the researcher in the construction of categories and theoretical interpretations (Charmaz, 2014). These traditions share important historical and procedural roots, yet their differences are substantive rather than merely terminological. They vary in their assumptions regarding emergence, researcher positioning, the function of coding, the use of prior literature, and the way theoretical integration is achieved (Rieger, 2019).

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The coexistence of multiple grounded theory traditions has created methodological richness, but it has also contributed to inconsistency in the way grounded theory is designed, implemented, and reported. Studies may identify themselves as using "grounded theory" without clearly specifying which tradition has guided data collection and analysis, or they may combine procedures from different traditions without explaining the methodological rationale for doing so. Reviews of grounded theory applications have repeatedly identified this problem. In educational research, for example, substantial variation has been observed in how grounded theory approaches are named and operationalized, with some studies reporting procedures that do not align fully with the grounded theory tradition they claim to follow (Stough & Lee, 2021). More recent evaluations similarly indicate that inadequate explanation of sampling, coding, category development, and theoretical integration can make it difficult to determine whether a study has actually implemented grounded theory coherently (Ali et al., 2024). Such methodological ambiguity is consequential because grounded theory cannot be identified simply by the presence of interviews, coding, categories, or qualitative analysis; its credibility depends on the relationship among methodological logic, analytical decisions, and the theoretical product generated from the data.

This concern is particularly important for Glaserian classic grounded theory because several of its defining concepts are frequently used without their full methodological implications. One example is the "main concern." In the classic approach, the main concern is not simply the researcher's initial research problem, the most frequently mentioned interview topic, or a broad theme identified during analysis. It refers to the recurring problem, pressure, or issue that participants are continually attempting to resolve within the substantive area. Identifying this concern requires open coding, constant comparison, and conceptual analysis rather than prior specification (Connor et al., 2024). Recent methodological work has emphasized that inadequate attention to the main concern can fundamentally alter the logic of a classic grounded theory study because the main concern provides the analytical basis for developing a core category that explains the process through which participants address the problem (Connor et al., 2024). A systematic review of classic grounded theory applications has likewise demonstrated continuing variation in the extent to which core Glaserian procedures are reported and implemented consistently, reinforcing the need for clearer methodological guidance (Connor et al., 2026).

The core category is similarly vulnerable to misunderstanding. In classic grounded theory, it is not selected simply because a code occurs frequently or because it provides a convenient title for the results. The core category must have substantial explanatory power, recur meaningfully across the developing analysis, relate conceptually to other categories, and account for how participants resolve or manage the main concern. Once a core category begins to emerge, coding becomes increasingly selective, and subsequent data collection is guided by the need to develop, refine, and saturate the core and related categories (Glaser, 1998). This shift also marks the transition from initial purposive access to the field toward theoretical sampling. Theoretical sampling is therefore not synonymous with purposive sampling performed before analysis. It is an emergent process in which decisions about what data to collect next, from whom, or from which sources are directed by conceptual gaps identified in the developing theory (Holton & Walsh, 2017; Malone & Carmichael, 2025). Failure to distinguish these forms of sampling can obscure the iterative relationship between data collection and theory development that is essential to grounded theory.

Memo writing constitutes another crucial component of this iterative analytical architecture. In classic grounded theory, memos are not merely procedural notes or summaries of interview content; they are sites of theory development in which researchers record conceptual ideas, comparisons, possible relationships, unresolved questions, and directions for theoretical sampling. Through memo writing, the analysis moves progressively away from descriptive accounts and toward abstraction and conceptual integration (Glaser, 1978). As categories become sufficiently developed, theoretical coding is used to identify how substantive categories relate to the core category and to one another. Glaser's treatment of theoretical coding emphasizes that theoretical relationships should not be predetermined by a single mandatory model; rather, theoretical codes offer multiple possible ways of conceptualizing relationships, such as processes, linkages, dimensions, strategies, cycles, conditions, or interactions, depending on what the data support (Glaser, 2005). The final theory should therefore represent an emergent conceptual integration rather than a rearrangement of categories within an externally imposed structure.

Confusion between grounded theory and thematic analysis presents another important methodological challenge. Thematic analysis is a rigorous and flexible method for identifying, interpreting, and organizing patterns of meaning across qualitative datasets, but it does not necessarily require theoretical sampling, the emergence of a main concern, development of a core category, or production of a grounded conceptual theory (Braun & Clarke, 2022). Contemporary guidance on thematic analysis has emphasized the importance of methodological coherence and warned against combining procedures from different qualitative traditions without understanding their assumptions and purposes (Braun et al., 2023). Consequently, a study that organizes coded interview material into descriptive or interpretive themes may be methodologically sound as thematic analysis while still differing fundamentally from classic grounded theory. The problem arises not from choosing one method rather than another, but from claiming one methodological identity while implementing the logic of another. Clear differentiation is therefore necessary for researchers, readers, reviewers, and editors to evaluate whether the analytical procedures are congruent with the method claimed.

These issues are especially salient in applied educational and technological research, where investigators frequently seek to understand complex processes that connect formal education with professional practice, innovation, industry, and entrepreneurship. Engineering education provides a particularly suitable substantive context because technological development increasingly requires more than mastery of disciplinary theory. Changes in technology and engineering practice have progressively expanded expectations surrounding creativity, problem solving, application of knowledge, interaction with industry, and engagement with technological and entrepreneurial contexts (Bagherzadeh et al., 2017b). Previous research examining the evolution of technology and engineering education has emphasized the importance of integrating technological dimensions more directly into educational structures and of reducing the separation between academic preparation and technological practice (Bagherzadeh et al., 2017b). A related empirical investigation using classic grounded theory examined engineering education with an emphasis on technological education and demonstrated how qualitative data from inventors, technology developers, and knowledge-based entrepreneurs could be conceptually developed into a grounded curricular explanation (Bagherzadeh et al., 2017a). Such an empirical case provides a useful context not simply for revisiting substantive findings, but for demonstrating what methodological decisions actually look like as an analysis moves from raw data toward a main concern, core category, theoretical sampling, theoretical coding, and final conceptual theory.

A methodological tutorial based on a worked empirical illustration can therefore address a gap that conventional descriptions of grounded theory do not always resolve. Methodological publications may explain concepts such as open coding, constant comparison, saturation, or theoretical sampling independently, yet researchers—particularly graduate students and early-career investigators—may still struggle to determine when one analytical operation gives way to another, what evidence justifies those decisions, and how the movement from raw data to theory should be reported transparently. Methodological articles are specifically suited to clarifying such procedural and conceptual problems because their central subject is not a new substantive phenomenon but the design, execution, analysis, or reporting of research methods themselves (Mbuagbaw et al., 2020). A methodological tutorial goes further by showing researchers how a method is implemented, identifying decision points, explaining the rationale underlying those decisions, and linking abstract methodological principles to a concrete application (Yan, 2020). This format is therefore particularly appropriate for clarifying classic grounded theory, in which methodological coherence depends not merely on completing a prescribed sequence of steps but on maintaining an emergence-oriented logic throughout the study.

The need for such clarification has increased as grounded theory continues to be used across disciplines that differ substantially in research traditions and reporting expectations. Contemporary methodological overviews continue to present grounded theory as a powerful approach for investigating social and behavioral processes, especially when researchers seek explanations of how individuals respond to recurring problems or navigate changing circumstances (Malone & Carmichael, 2025). At the same time, growing scrutiny of published grounded theory studies indicates that methodological labels alone provide insufficient assurance of methodological quality (Connor et al., 2026). A study may report open coding but then impose a predetermined paradigm; it may claim theoretical sampling while selecting all participants in advance according to demographic quotas; it may identify a “core category” that is essentially a high-frequency theme; or it may present a collection of categories without demonstrating how they were theoretically integrated. These problems reduce transparency and make it difficult for readers to assess

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whether the resulting theory genuinely emerged from the analytical process.

A further difficulty concerns how methodological stages are represented in research reports. For explanatory purposes, classic grounded theory is often described sequentially: researchers enter a substantive area, conduct open coding, identify the main concern, move toward selective coding, engage in theoretical sampling, reach theoretical saturation, and then integrate categories through theoretical coding. In actual research, however, these processes overlap extensively. Memo writing begins with early analysis, comparisons occur continuously, possible relationships are recorded before categories are fully developed, and theoretical sampling evolves in response to the growth of concepts. Treating these processes as rigidly separate procedural boxes can misrepresent the recursive character of grounded theory (Glaser, 1998). Similarly, theoretical saturation should not be reduced to a predetermined number of interviews or codes. It refers to the point at which additional data no longer contribute conceptually important properties or relationships to the categories relevant to the emerging theory (Glaser, 1978). Reporting must therefore make visible not only what procedures were nominally performed but also how analytical decisions were generated by the developing conceptual structure.

The methodological distinction between classic grounded theory and alternative approaches should consequently be understood as a matter of internal coherence rather than methodological hierarchy. The systematic Strauss–Corbin tradition offers useful procedures when researchers seek structured explanatory relationships among conditions, actions, and consequences (Corbin & Strauss, 2015); constructivist grounded theory is appropriate when researchers wish to foreground situated interpretation, co-construction, and researcher reflexivity (Charmaz, 2014); and thematic analysis provides a flexible and theoretically informed approach when the primary aim is to identify and interpret patterns of meaning rather than to generate a theory centered on a main concern and its resolution (Braun & Clarke, 2022; Braun et al., 2023). Classic grounded theory is most coherent when the research objective is specifically to discover a recurrent participant concern and generate an emergent conceptual explanation of how that concern is continually managed or resolved (Glaser, 1992). Methodological quality therefore requires researchers to select an approach that matches the intended knowledge product and then follow its analytical logic consistently.

Against this background, the empirical illustration involving inventor-entrepreneurs, technology developers, innovative engineers, and knowledge-based business actors offers a particularly instructive case for demonstrating classic grounded theory in practice. The original substantive investigation was situated within engineering education and technological education and included participants with direct experience in invention, technological development, industrial engagement, and commercialization (Bagherzadeh et al., 2017a). Rather than treating the original substantive findings merely as conclusions about curriculum development, the documented analytical materials permit reconstruction of the methodological trajectory from early interview data and substantive codes to the identification of insufficient attention to technological literacy as the participants' main concern, the emergence of injecting technological literacy into engineering education as the core category, and the eventual integration of the categories through a linkage-based theoretical structure. This worked example therefore provides an opportunity to demonstrate how emergence, rather than procedural labeling alone, differentiates Glaserian classic grounded theory from adjacent qualitative traditions.

The methodological problem addressed in the present article is thus the recurring gap between claiming to conduct Glaserian classic grounded theory and demonstrating, in sufficient analytical detail, that the actual research process follows its emergence-oriented logic. Existing methodological literature provides strong conceptual foundations for grounded theory and increasingly sophisticated guidance on its application (Ali et al., 2024; Cullen & Brennan, 2021), yet researchers still require concrete illustrations showing how the main concern differs from an initial research problem, how purposive entry into a field differs from theoretical sampling, how selective coding follows conceptual emergence rather than arbitrary narrowing, how theoretical saturation is judged conceptually, and how theoretical coding integrates categories without imposing a predetermined causal model. By positioning these methodological decisions alongside a worked empirical example, a tutorial approach can make the otherwise abstract logic of classic grounded theory more visible, auditable, and transferable to future research.

Accordingly, the aim of this study was to explicate the distinctive methodological logic and decision processes of Glaserian classic grounded theory and to demonstrate their practical implementation through a worked empirical

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illustration involving inventor-entrepreneurs in the context of engineering and technological education.

2. Methods and Materials

2.1. Study Design and Participants

The present study was designed as a methodological review and tutorial situated within the qualitative research tradition and focused specifically on the practical logic, analytical decisions, and reporting requirements of Glaserian classic grounded theory. More precisely, the study adopted a methodological tutorial design rather than a systematic review, scoping review, or conventional empirical investigation. The purpose was not to estimate the prevalence of particular methodological practices, comprehensively retrieve all publications on grounded theory, quantitatively assess the quality of existing studies, or generate new substantive findings concerning engineering education or entrepreneurship. Instead, the review component was designed as a purposive conceptual examination of methodological materials relevant to the foundations and practical implementation of classic grounded theory. Consistent with the methodological tutorial approach described by Yan (2020) and the principles for methodological studies articulated by Mbuagbaw et al. (2020), the study sought to clarify a specific methodological problem, explicate the logic underlying key methodological decisions, identify the evidence required for defensible implementation, and demonstrate how the method operates in an actual research context. The central methodological problem concerned the frequent inconsistency between researchers' claims that they have employed Glaserian classic grounded theory and their simultaneous use of procedures derived from other traditions, particularly the systematic Strauss–Corbin approach, Charmaz's constructivist grounded theory, and thematic analysis. Accordingly, the analytical review concentrated on the conceptual and procedural boundaries of Glaserian classic grounded theory, with particular attention to emergence rather than forcing, the main concern, the core category, open and selective coding, constant comparison, memo writing, theoretical sampling, theoretical saturation, theoretical coding, and the integration of the final theory.

The analytical materials were derived from two complementary sources. The first consisted of foundational publications on classic grounded theory, particularly the works of Glaser and of Glaser and Strauss, together with contemporary methodological literature addressing distinctions among grounded theory traditions, coding practices, theoretical sampling, identification of the main concern, theoretical integration, reporting transparency, and criteria for evaluating grounded theory quality. Sources were selected purposively on the basis of their direct relevance to the conceptual foundations, practical implementation, methodological decision points, reporting procedures, or quality criteria of classic grounded theory. Because the objective was methodological clarification and conceptual synthesis rather than exhaustive evidence retrieval, the literature component did not employ the procedures of a systematic or scoping review. The second source comprised anonymized materials from a previously completed qualitative investigation employing Glaserian classic grounded theory, together with related publications by the researchers. This empirical material was used as a worked illustration through which the movement from raw data to open coding, emergence of the main concern, selective coding, theoretical sampling, development of the core category, theoretical coding, and final theoretical integration could be reconstructed. The empirical illustration was therefore used to demonstrate methodological decisions rather than to make new substantive generalizations about engineering education.

The empirical sample consisted of exactly 10 participants drawn from entrepreneurial inventors, technology developers, innovative engineers, and owners of knowledge-based companies in the fields of electrical engineering, electronics, and computer engineering. Participants had direct experience with invention, technological development, product development and commercialization, interaction with industry, and the establishment or management of technology-oriented businesses. Initial participants were selected purposively and on the basis of these eligibility characteristics because their experience provided direct access to the substantive area of interest, namely engineering education and technological education. This initial selection should be distinguished from theoretical sampling. At the point of entry into the field, neither the participants' main concern nor the core category had yet emerged; therefore, there was not yet a theoretically developed category capable of directing subsequent sampling. Once relevant concepts and the main concern began to emerge through open coding and constant comparison, subsequent data collection and examination of documentary materials became increasingly theoretically directed toward elaborating, differentiating, and saturating the developing categories. Thus, the sampling process

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reflected the Glaserian distinction between purposive, criterion-based entry into the substantive area and theoretically driven sampling that becomes possible only after analytically relevant categories have begun to emerge (Glaser & Strauss, 1967; Glaser, 1978, 1992; Connor et al., 2024).

2.2. Instruments

The empirical material used in the worked illustration was generated primarily through in-depth semi-structured interviews, supplemented by field notes, expanded post-interview notes, analytical memos, documentary evidence, and relevant materials concerning technological literacy, technology education, and engineering education. Each interview lasted approximately 60 to 90 minutes. The interview format was sufficiently structured to facilitate entry into the substantive area and ensure discussion of participants' experiences in engineering, technological development, innovation, industry, and commercialization, while remaining sufficiently open to prevent predetermined questions from functioning as fixed analytical categories. The initial guiding questions were therefore treated as conversational devices for entering the field and eliciting rich and varied data rather than as an a priori coding framework. During the initial phase of data collection, the interviews were oriented toward understanding participants' experiences and concerns and toward generating data capable of answering broad Glaserian analytical questions such as what was occurring in the substantive area, what participants were primarily concerned about, and how they attempted to address, manage, or resolve that concern.

Because the interviews involved potentially sensitive information regarding inventions, products, technological activities, commercial development, and business practices, audio recording was not used. Instead, detailed notes were produced during each interview. Immediately after the completion of each interview, these notes were systematically expanded while the interaction remained fresh in the researcher's memory. The expanded notes were prepared with the intention of preserving, as closely as possible, the sequence of the participant's account, the language used, the substantive meaning of the statements, and the contextual features required for subsequent interpretation. These expanded interview records, together with field notes and analytical memos, constituted the principal empirical material for coding and constant comparison. Documentary materials were also incorporated as comparative data when they became theoretically relevant. Documents concerning technological literacy, technology education, and engineering education were not used to construct an advance coding framework or to impose established concepts on the interview material. Rather, they were brought into comparison with emerging concepts in order to clarify their properties, dimensions, boundaries, and relationships and to increase theoretical sensitivity after an analytical focus had begun to emerge.

Memo writing functioned simultaneously as a data-management and theory-development tool throughout the research process. Analytical memos were initiated alongside early coding and were used to record conceptual observations, comparisons between incidents, provisional relationships among codes and categories, unresolved analytical questions, and emerging ideas concerning the main concern and potential core category. They also served as a record of decisions regarding the direction of subsequent data collection and theoretical sampling. In this manner, the data collection tools were not treated as independent instruments operating before analysis; rather, consistent with classic grounded theory, interviewing, note expansion, documentary examination, memo writing, comparison, and subsequent data collection operated recursively. As concepts acquired greater analytical relevance, later questions and data collection became more focused on information capable of extending, refining, challenging, or saturating the developing conceptual explanation.

2.3. Data Analysis

Data collection and analysis proceeded concurrently in accordance with the principles of Glaserian classic grounded theory. Analysis began after each interview through close reading and rereading of the expanded interview notes. The first analytical level was substantive coding, which incorporated both open coding and selective coding. During open coding, the empirical material was examined without imposing predetermined categories, causal models, thematic frameworks, or the Strauss–Corbin coding paradigm. Coding was conducted line by line while retaining flexibility in the definition of the unit of analysis. The analytical unit was therefore not mechanically restricted to an individual sentence; any segment conveying a sufficiently complete meaning, ranging from several words to several sentences, lines, or an entire paragraph, could constitute a coding unit. Throughout this phase, the researcher repeatedly asked what was occurring in the data, what the participants' principal concern appeared to be, and how they were attempting to address or resolve it. Initial codes were treated as provisional conceptualizations rather than as fixed categories, and their relevance was continually assessed through comparison with additional incidents and data.

Constant comparison constituted the central analytical mechanism throughout the study. Data were compared with other data, incidents with incidents, codes with codes, codes with developing categories, and categories with other categories. Concepts that lacked meaningful relevance to the emerging main concern or core category were reconsidered, merged with other concepts where appropriate, retained provisionally at the margins of the analysis, or excluded from further theoretical development. Conversely, conceptually relevant codes were progressively refined so that their properties, dimensions, variations, and relationships became increasingly explicit. Memo writing occurred throughout this process and provided the conceptual bridge between coding and theory development. Rather than merely summarizing interview content, memos captured theoretical ideas arising from comparisons, identified conceptual gaps, recorded possible relationships, and indicated what additional data were required. This iterative interaction among coding, comparison, memo writing, and further data collection prevented the analytical process from becoming a simple descriptive categorization of participants' statements.

Through repeated open coding, comparison, and memo review, the analysis progressively identified insufficient attention to technological literacy in engineering education as the main concern evident in the empirical material. This main concern was analytically distinguished from the core category. In Glaserian classic grounded theory, the main concern represents the prominent problem or pressure with which participants are continually engaged, whereas the core category explains the principal process through which that concern is addressed, managed, or resolved. Once the main concern had emerged with sufficient conceptual clarity, analysis moved from broad open coding toward selective coding. Subsequent coding and data collection were increasingly focused on concepts that could clarify the process through which participants responded to insufficient attention to technological literacy. At this stage, analytical questions were reformulated around issues such as how technological actors attempted to overcome this problem, what capabilities and experiences facilitated technological education, how industrial experience, creative thinking, problem solving, teamwork, management, and economic capability contributed to this process, and what higher-level concept could theoretically integrate these actions and conditions.

Selective coding was accompanied by theoretical sampling. Rather than treating all subsequent information as equally important, the researcher pursued data and documents capable of elaborating the properties and relationships of categories relevant to the emerging theoretical explanation. When a memo indicated that the role of a particular concept, such as industrial experience, remained insufficiently developed, subsequent data and documentary materials were examined specifically to clarify that relationship. The purpose of theoretical sampling was therefore not to increase the numerical size or representativeness of the sample but to strengthen conceptual development. Through this process, concepts including creative thinking, problem solving, teamwork, industrial experience, individual and group management, and economic capability were progressively examined in relation to the main concern. Continuous comparison and memo development eventually resulted in the endogenous formulation of injecting technological literacy into engineering education as the core category with the greatest capacity to account for the participants' efforts to manage or resolve the identified main concern.

Analysis continued until theoretical saturation was reached. Theoretical saturation was defined conceptually rather than numerically; it was considered to have occurred when additional data no longer contributed substantively new properties, dimensions, variations, or conceptual relationships to the core category and the categories connected with it. Across the analytical process, 367 initial codes and 70 main and subsidiary codes were generated. These numerical counts were not themselves treated as evidence of saturation but reflected the amount of conceptual material progressively reduced, compared, abstracted, and integrated during theory development. Constant comparison remained active throughout this process, ensuring that the developing concepts were continually tested against the available empirical materials rather than being retained merely because of their frequency or apparent descriptive importance.

Following sufficient development of the core category and related substantive categories, the analysis proceeded to theoretical coding. At this level, the objective was no longer to produce additional descriptive or substantive codes but to determine how the developed categories were conceptually related to the core category and to one another. Theoretical

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coding was deliberately distinguished from axial coding and from the use of a predetermined causal paradigm. Relationships were allowed to emerge through the sorting and comparison of theoretical memos rather than being classified in advance as causal conditions, context, intervening conditions, strategies, or consequences. The analysis considered potential theoretical relationships involving processes, conditions, consequences, strategies, dimensions, cycles, interactions, means–ends relations, and linkages, while retaining only the relational structure supported by the data and memos. Sorting and rereading the accumulated memos indicated reciprocal movement and interaction among personal, social, educational, and industrial environments. On this basis, the theoretical code family of linkages provided the most appropriate integrative structure. The core category of injecting technological literacy into engineering education was consequently integrated through a pendular pattern of technological linkages among personal, social, educational, and industrial environments, culminating in the formulation of the final conceptual theory described as the Pendular Technological Curriculum in Engineering Education. Throughout analysis, the defining methodological principle was emergence rather than forcing: substantive categories, the main concern, the core category, directions for theoretical sampling, and the final theoretical relationships were progressively developed through open coding, constant comparison, memo writing, selective coding, theoretical sampling, saturation, and theoretical coding rather than being specified before engagement with the empirical material (Glaser & Strauss, 1967; Glaser, 1978, 1992, 1998, 2005).

3. Findings and Results

The empirical illustration included exactly 10 participants selected from professional groups with direct and substantial involvement in technological innovation and commercialization. The participants comprised entrepreneurial inventors, technology developers, innovative engineers, and owners or managers of knowledge-based companies operating in electrical engineering, electronics, and computer engineering. Their relevance to the empirical illustration derived primarily from their direct experience with invention, development of technological products, interaction between academic engineering knowledge and industrial practice, establishment or management of knowledge-based enterprises, and commercialization of technological products. Accordingly, the sample was characterized by experiential and professional relevance to the substantive area of engineering education and technological education rather than by statistical representativeness. The initial participants had been selected purposively and according to these experiential criteria to provide access to the substantive field. As the analysis progressed and conceptual categories began to emerge, subsequent attention to data and documentary materials became theoretically directed toward elaborating the developing concepts. The available source material did not report participants' age distribution, sex distribution, marital status, or formal educational-level frequencies; consequently, no numerical values for these characteristics were reconstructed. The characteristics that can be reported with certainty are therefore the sample size of 10, professional involvement in invention and technological entrepreneurship, disciplinary connection to electrical engineering, electronics, and computer engineering, and direct experience with technology development, industry, knowledge-based enterprise activity, and product commercialization.

The findings were organized in accordance with the methodological logic of Glaserian classic grounded theory. The first level of findings concerns the conceptual boundary between classic grounded theory and three closely related qualitative approaches. The subsequent findings reconstruct the empirical analytical trajectory, beginning with entry into the substantive area, proceeding through open coding and identification of the main concern, moving to selective coding and theoretical sampling, and culminating in development of the core category, theoretical integration, and formulation of the final theory.

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Table 1

Conceptual and Operational Distinctions Among Glaserian Classic Grounded Theory and Related Qualitative Approaches

Dimension of Comparison	Glaserian Classic Grounded Theory	Systematic Strauss–Corbin Grounded Theory	Charmaz's Constructivist Grounded Theory	Reflexive Thematic Analysis
Primary purpose	Generation of a conceptual theory explaining participants' main concern and the process through which it is resolved or managed	Systematic explanation of a phenomenon through relationships among conditions, context, action/interaction, and consequences	Development of a situated interpretation or theory concerning meaning construction and social processes	Identification and interpretation of meaningful patterns or themes within a dataset
Principal guiding question	What is the main concern of participants, and how do they continually resolve or manage it?	What conditions shape the phenomenon, what actions/interactions occur, and what consequences follow?	How do participants construct meaning in context, and how is the researcher implicated in that construction?	What meaningful patterns relevant to the research question can be identified in the data?
Position at entry to the field	Entry occurs through a broad substantive area of interest; the main concern, core category, and final theory are not predetermined	A phenomenon can be progressively organized through a more systematic explanatory framework	The research problem is interpreted through interaction among participants, researcher, context, and situated meaning	Research questions guide identification and interpretation of patterned meaning
Beginning of analysis	Open coding accompanied by constant comparison to discover what is occurring and what participants are primarily concerned about	Open coding to identify concepts and categories	Initial coding, frequently detailed and close to the data	Familiarization with data followed by coding for meaningful patterns
Intermediate analytical movement	Emergence of the main concern and core category, followed by selective coding	Axial coding and organization of categories through the coding paradigm	Focused coding emphasizing analytically significant initial codes	Development, review, integration, separation, and refinement of candidate themes
Use of predetermined analytical structure	Avoided; categories and relationships should emerge rather than be forced	More explicit use of an organizing paradigm involving conditions, phenomenon, context, actions/interactions, and consequences	Interpretation is explicitly situated and acknowledges co-construction	Themes are interpretive constructions developed in relation to the research question
Role of the main concern	Central; represents the recurrent problem or pressure participants seek to resolve, reduce, or manage	Not an obligatory organizing construct in the Glaserian sense	Not necessarily treated as the central analytic requirement	Not required
Role of the core category	Central integrating category explaining the resolution or management of the main concern	A central category may organize the explanatory model	Categories can become analytically central, but their meaning is interpreted as constructed and situated	A core category is not required
Role of memo writing	Development of concepts and conceptual relationships, guidance of theoretical sampling, and preparation for theoretical integration	Documentation of category properties, dimensions, and paradigmatic relationships	Analytical development combined with researcher reflexivity and examination of interpretive construction	Documentation of interpretive and analytical decisions; not necessarily theory-generating memos
Sampling after initial entry	Theoretical sampling is directed by emerging categories to develop, modify, and saturate the core category	Theoretical sampling can be used to elaborate categories and paradigmatic relationships	Theoretical sampling may be used to deepen categories and interpretations	Sampling is generally established according to the study design; theoretical sampling is not a methodological requirement
Final integration	Theoretical coding identifies an emergent relationship such as process, linkage, interaction, cycle, condition, strategy, or other conceptual pattern	Selective coding integrates categories into a systematic explanatory model or narrative	Development of a situated constructivist interpretation or theory	Definition and organization of themes into an interpretive account or thematic map
Expected final product	Modifiable conceptual theory grounded in data	Systematic explanatory model or theory	Situated constructivist interpretation or theory	Themes and thematic interpretation
Appropriate criterion for selection	Appropriate when the aim is to discover a process through which a main concern is resolved and to generate an emergent conceptual theory	Appropriate when the aim is to systematically organize a phenomenon in terms of conditions, actions/interactions, and consequences	Appropriate when the aim concerns situated meaning construction and the interpretive role of the researcher	Appropriate when the aim is to identify and interpret meaningful patterns rather than construct a grounded conceptual theory
Key methodological references	Glaser & Strauss, 1967; Glaser, 1978, 1992, 2005	Strauss & Corbin, 1998; Corbin & Strauss, 2015	Charmaz, 2014; Rieger, 2019	Braun & Clarke, 2022; Braun et al., 2023

As shown in Table 1, the analysis identified substantive methodological differences rather than merely terminological differences among the four approaches. The distinctive characteristic of Glaserian classic grounded theory was its organization around emergence, the identification of participants' main concern, and development of a core category explaining the process through which that concern is addressed. In this logic, neither the final phenomenon nor the structural relationships among categories are specified before analysis. The researcher initially enters a substantive area, engages in open coding and constant comparison, identifies the main concern as it becomes recurrently evident across incidents, and subsequently concentrates analysis on a core category capable of explaining how participants resolve or manage that concern. This trajectory differs from the systematic Strauss–Corbin approach, in which relationships among categories may be organized more explicitly through conditions, context, action/interaction strategies, and consequences. It also differs from Charmaz's constructivist grounded theory, in which interpretive co-construction, situated knowledge, and researcher reflexivity receive more explicit epistemological emphasis, and from reflexive thematic analysis, in which the central analytical task is the interpretation of patterned meaning rather than the generation of a theory organized around a main concern and core category. The comparison therefore demonstrated that methodological coherence depends on alignment among the research objective, coding procedures, sampling logic, memo writing, integration strategy, and intended analytical product. Merely employing terms such as "open coding," "core category," or "theoretical saturation" does not establish that an analysis has followed the Glaserian tradition if the actual analytical structure is based on a predetermined paradigm or the production of themes rather than an emergent conceptual theory.

The empirical reconstruction began with the substantive area of engineering education and technological education. Importantly, this substantive area was not treated as a predetermined central phenomenon, main concern, or core category. The analytical process remained open to determining what participants themselves repeatedly treated as problematic and how they attempted to address it. Initial interview materials generated numerous codes concerning the dominance of theoretical instruction, separation between university and industry, limited opportunities for practical experience, inability to translate theoretical knowledge into technological action, weak real-world problem-solving capacity, credentialism, and uncertainty concerning professional preparation. Constant comparison gradually demonstrated that these apparently distinct codes converged conceptually around a broader recurring problem: insufficient attention to technological literacy in engineering education. Once this main concern had emerged, analytical attention shifted from broad open coding toward selective coding and theoretical sampling focused on the processes through which this concern could be resolved.

Table 2

Analytical Progression from the Substantive Area to the Final Grounded Theory

Analytical Stage	Analytical Focus	Evidence Emerging From the Data	Methodological Decision	Resulting Conceptual Development
Entry into the substantive area	Engineering education and technological education	Participants possessed direct experience of invention, technology development, industrial activity, knowledge-based business, and commercialization	Treat the field only as an area of interest rather than as a predetermined phenomenon or core category	Open substantive field maintained
Initial purposive sampling	Individuals capable of providing rich experiential data on technology and engineering practice	Entrepreneurial inventors, technology developers, innovative engineers, and owners of knowledge-based firms	Select participants on experiential relevance before any category exists to guide theoretical sampling	Initial access to information-rich cases
Open coding	What is occurring in the data? What appears problematic to participants?	Dominance of theoretical education, university–industry distance, difficulty converting knowledge into action, limited practical experience, weak real-world problem solving	Code openly without placing statements into predetermined categories such as causes, contexts, strategies, or consequences	Large pool of provisional substantive codes
Constant comparison	Which incidents and codes represent similar underlying processes?	Repeated convergence of educational and industrial difficulties around inadequate preparation for technological action	Compare data with data, code with code, and codes with developing categories	Increasing conceptual abstraction
Emergence of the main concern	What recurring problem are participants attempting to manage?	Multiple apparently separate educational deficiencies represented a broader lack of technological literacy	Conceptualize the recurring problem rather than select the most frequent descriptive code	Main concern: Insufficient attention to technological literacy in engineering education

Selective coding	How are participants attempting to address the emerging main concern?	Emphasis on creative thinking, problem solving, teamwork, industrial experience, management abilities, and economic capability	Concentrate coding on data relevant to the emerging central process	Development of conceptually relevant categories
Theoretical sampling	What additional information is required to clarify properties and relationships?	Some relationships, such as the contribution of industrial experience to converting theoretical knowledge into technological action, required further elaboration	Pursue subsequent data, documents, and comparisons according to conceptual gaps	Greater density and specification of categories
Development of the core category	What concept best explains how the main concern is managed or resolved?	Participants' proposed actions and experiences converged around integrating technological literacy into engineering education	Compare candidate categories according to explanatory power and ability to integrate other categories	Core category: Injecting technological literacy into engineering education
Theoretical saturation	Are new data adding important properties, dimensions, or relationships?	Additional material increasingly confirmed rather than substantially altered developed conceptual relationships	Continue comparison until further data cease to contribute substantively new conceptual properties	Categories achieve adequate conceptual density
Theoretical coding	How are the developed categories related to the core category?	Personal, social, educational, and industrial environments showed reciprocal rather than linear relations	Examine theoretical relationships without imposing a predetermined causal model	"Linkages" identified as the most appropriate theoretical code family
Theoretical integration	What conceptual pattern unifies the developed categories?	Continuous reciprocal movement among personal, social, educational, and industrial environments	Sort and integrate memos around the core category and emergent linkage pattern	Pendular technological linkage among four environments
Final theory	What conceptual explanation accounts for resolution of the main concern?	Technological education emerged as the product of reciprocal connections rather than a single educational intervention	Integrate core category and related categories into a conceptual explanatory formulation	Pendular Technological Curriculum in Engineering Education

Table 2 demonstrates that the analytical outcome was not produced by beginning with a predefined model and filling its components with interview data. Instead, the trajectory moved progressively from a broad substantive area to a more abstract conceptual explanation. The starting point, "engineering education and technological education," only delineated the field within which participants' concerns could be explored. During open coding, statements concerning theoretical dominance, weak university–industry relations, inadequate practical learning, limited real-world problem solving, and difficulties translating knowledge into technological action remained provisional and independent. Constant comparison revealed that these codes could be understood as manifestations of a more pervasive problem, namely insufficient attention to technological literacy in engineering education. This distinction was analytically important because the main concern was not simply the most frequently mentioned item but the concept capable of explaining a range of recurring difficulties experienced by participants. Once this concern emerged, the analytical process became more focused. Selective coding and theoretically directed data examination investigated how participants sought to resolve the problem, leading to the development of concepts associated with creativity, problem solving, teamwork, industrial experience, managerial ability, and economic capability. Their conceptual convergence supported development of "injecting technological literacy into engineering education" as the core category. Finally, memo sorting and theoretical coding showed that these processes operated through reciprocal connections among four environments rather than through a simple linear sequence, resulting in the formulation of the Pendular Technological Curriculum in Engineering Education.

The open-coding process generated substantial conceptual material. Across the complete analysis, 367 initial codes and 70 main and subsidiary codes were obtained. These numerical totals were not interpreted as indicators of theoretical saturation in themselves. Instead, they represented the volume of conceptual material from which increasingly abstract categories were developed through comparison, reduction, integration, and theoretical elaboration. The analytical importance of a code was therefore determined by its conceptual relevance to the developing explanation rather than its numerical frequency. For example, statements indicating that engineering students could master formulas yet remained unable to convert real industrial problems into technological solutions generated multiple provisional codes, including dominance of theoretical education, university–industry distance, inability to transform knowledge into practice, lack of practical experience, and weak real-world problem solving. These codes became analytically meaningful when constant comparison revealed their relationship to a common underlying concern.

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Table 3

Development of the Main Concern and Core Category Through Substantive Coding

Level of Analysis	Illustrative Empirical Indicators or Codes	Conceptual Interpretation	Role in the Emerging Theory
Initial substantive codes concerning educational orientation	Dominance of theoretical education; emphasis on formulas and abstract knowledge; credentialism	Engineering education is disproportionately oriented toward formal and theoretical knowledge	Contributed evidence that conventional preparation insufficiently supports technological action
Initial substantive codes concerning university–industry separation	Distance between university and industry; weak exposure to industrial environments; insufficient contact with real technological problems	Academic learning is insufficiently connected with contexts in which technological knowledge is enacted	Helped connect educational shortcomings to limitations in practical technological competence
Initial substantive codes concerning application of knowledge	Inability to transform knowledge into practice; difficulty converting industrial problems into technological solutions	Possession of disciplinary knowledge does not automatically produce technological capability	Supported distinction between theoretical competence and technological literacy
Initial substantive codes concerning experience	Limited practical experience; insufficient industrial experience; restricted project-based exposure	Technological capability requires experiential engagement with authentic problems and environments	Directed later theoretical sampling toward industrial and experiential learning
Initial substantive codes concerning problem solving	Weak real-world problem solving; uncertainty when confronting non-routine technological situations	Technological action requires problem definition, adaptation, and solution generation beyond routine academic exercises	Became an important property of the emerging resolution process
Initial substantive codes concerning professional development	Student confusion; inadequate professional orientation; difficulty transitioning from university to industrial practice	Deficiencies in technological preparation influence professional readiness and identity	Connected educational practices with personal and professional environments
Higher-order convergence of problem-oriented codes	Recurrent combination of theoretical dominance, weak industrial connection, insufficient experience, and limited applied problem solving	Apparently separate deficiencies represent manifestations of one broader recurring problem	Main concern: Insufficient attention to technological literacy in engineering education
Selectively developed concept: creative thinking	Ability to generate novel approaches, alternatives, and innovative technological responses	Technological literacy requires productive and generative thinking rather than reproduction of learned procedures	Property contributing to resolution of the main concern
Selectively developed concept: problem solving	Ability to work with authentic technological and industrial problems	Technological competence develops through engagement with uncertain and practical problems	Central mechanism connecting academic knowledge with technological action
Selectively developed concept: teamwork	Collaboration, interaction, and collective problem solving	Technological development is socially organized rather than exclusively individual	Linked the core process to the social environment
Selectively developed concept: industrial experience	Exposure to authentic industry, real projects, production processes, and technological constraints	Industrial settings provide experiential conditions in which theoretical knowledge becomes actionable	Linked educational and industrial environments
Selectively developed concept: individual and group management	Self-management, project organization, coordination, and collaborative management	Technological action requires organizational and managerial capability in addition to technical knowledge	Expanded the core process beyond narrowly technical competence
Selectively developed concept: economic capability	Awareness of economic feasibility, commercialization, value creation, and entrepreneurial considerations	Technological literacy involves understanding how technological ideas become viable products or ventures	Connected technological education to entrepreneurship and commercialization
Conceptual integration of resolution-oriented categories	Creative thinking, problem solving, teamwork, industrial experience, management, and economic capability operate as interconnected means of strengthening technological competence	Resolution requires incorporation of technological literacy throughout engineering learning rather than isolated remediation	Core category: Injecting technological literacy into engineering education
Analytical distinction	Main concern = the recurring problem; core category = the principal process through which the problem is resolved or managed	The two concepts are related but not interchangeable	Provides the central explanatory architecture of the grounded theory

Table 3 shows the conceptual movement from descriptive indicators to increasingly abstract substantive categories. During the initial phase, codes such as dominance of theoretical instruction, distance between university and industry, inadequate practical experience, and weak real-world problem solving could have been presented simply as separate educational deficiencies. The constant comparative method, however, required examination of what these codes collectively indicated about the participants' recurring difficulty. Their convergence resulted in the formulation of “insufficient attention to technological literacy in engineering education” as the main concern. This formulation condensed a broad range of empirical incidents without reducing the main concern to a single descriptive complaint. Once that concern had become analytically stable, later coding was deliberately concentrated on the processes relevant to its resolution. Creative thinking, problem solving, teamwork, industrial experience, managerial capacity, and economic capability consequently became significant not because they were independently attractive curricular concepts but because the analysis showed how they contributed to a process through which insufficient technological literacy could be addressed. Their relationships progressively supported the core category “injecting technological literacy into engineering education.” The findings therefore demonstrate the critical distinction between the main concern and the core category: the former identifies the recurring problem experienced within the substantive field, whereas the latter provides an abstract account of the process through which participants attempt to manage or resolve that problem. This distinction preserved the explanatory rather than merely descriptive character of the grounded theory.

Following development of the core category and sufficient conceptual elaboration of the related categories, the analysis proceeded to theoretical coding. At this stage, the focus shifted from identifying additional substantive codes to determining the form of relationship among the developed categories. The data did not support a simple unidirectional sequence in which one fixed cause produced one educational strategy and then a discrete outcome. Instead, memo sorting and comparison showed reciprocal movement among personal, social, educational, and industrial environments. Industrial experience, for example, could bring authentic industrial problems into the educational environment; engagement with these problems could strengthen personal motivation, creativity, and professional orientation; collaborative activities could develop social interaction and teamwork; and the resulting learning experiences could subsequently alter students' readiness for participation in industry. This reciprocal structure made a linkage-based theoretical code more congruent with the data than a predetermined linear causal framework.

Table 4

Theoretical Integration of the Core Category Across Personal, Social, Educational, and Industrial Environments

Theoretical Environment	Principal Emerging Components	Contribution to the Core Category	Reciprocal Linkages With Other Environments	Theoretical Function
Personal environment	Creative thinking; problem-solving orientation; motivation; professional direction; individual management; capacity to transform knowledge into action	Develops the individual capabilities necessary for technological literacy and technological agency	Personal capability is strengthened through educational experiences and industrial exposure and subsequently affects participation in teamwork, learning, and professional practice	Represents the individual competence and agency through which technological literacy is enacted
Social environment	Teamwork; collaboration; communication; collective problem solving; group management; interaction with peers and professional actors	Establishes the interpersonal and collaborative capacities required for technological development	Social interaction is developed in educational projects and industrial settings and in turn strengthens personal capability and collective technological performance	Represents the relational infrastructure of technological learning and innovation
Educational environment	Engineering curriculum; practical and project-based learning; connection between theory and application; authentic problem solving; opportunities to develop technological literacy	Provides the formal educational context through which technological literacy can be deliberately incorporated into engineering preparation	Receives authentic problems and expectations from industry while shaping personal competencies and social collaboration that later return to professional contexts	Functions as a principal site for deliberate injection and development of technological literacy
Industrial environment	Authentic industrial problems; product development; technological constraints; commercialization experience; entrepreneurship; production and market realities	Provides real-world contexts in which technological literacy is tested, refined, and made consequential	Industrial experience informs curriculum and learning activities, influences personal and professional development, requires teamwork, and benefits from graduates with enhanced technological competence	Anchors technological education in authentic technological and economic practice
Integrating theoretical relationship	Reciprocal, continuous, and non-linear movement among the four environments	Prevents technological literacy from being treated as an isolated subject or single curricular intervention	Changes in one environment produce implications for and feedback from the other environments	Theoretical code family: Linkages

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Core process	Injection of technological literacy into engineering education	Organizes the substantive categories around the resolution of the main concern	Operates through continuous interaction among personal, social, educational, and industrial environments	Core category
Final conceptual pattern	Pendular technological linkage	Captures movement, interaction, feedback, and reciprocal influence rather than a fixed linear sequence	Theoretical movement occurs repeatedly among personal, social, educational, and industrial domains	Integrative theoretical pattern
Final theory	Pendular Technological Curriculum in Engineering Education	Explains how insufficient attention to technological literacy may be addressed through an integrated and reciprocally connected educational process	Integrates all four environments around the core category	Final grounded theory

As presented in Table 4, theoretical integration revealed that the substantive categories were more coherently explained through reciprocal linkages than through a linear causal arrangement. The personal environment incorporated capacities such as creative thinking, problem solving, motivation, professional orientation, and individual management; however, these capacities did not develop independently of the other environments. Authentic industrial exposure could stimulate motivation and provide problems requiring creative technological responses, while educational experiences could strengthen the knowledge and skills necessary to act effectively in industry. The social environment contributed teamwork, communication, collaborative problem solving, and group management, linking individual competence with the collective character of technological development. The educational environment constituted the formal site in which technological literacy could be intentionally incorporated through practical, experiential, project-based, and problem-centered learning. The industrial environment supplied authentic technological problems, constraints, product-development processes, commercialization requirements, entrepreneurial realities, and opportunities to test whether academic knowledge could be translated into technological action. Because influence moved repeatedly among these domains, the “linkages” family of theoretical codes provided the most appropriate mechanism for conceptual integration. The resulting pendular formulation emphasizes continuous movement and feedback: industrial problems can enter educational settings; educational experiences can alter personal competencies; personal development can strengthen participation in social and collaborative processes; social interactions can improve technological problem solving; and enhanced competencies can subsequently influence industrial engagement. Accordingly, the final theory, the Pendular Technological Curriculum in Engineering Education, conceptualizes technological education not as the product of one isolated curricular component but as an interconnected process arising from continuous reciprocal relationships among personal, social, educational, and industrial environments.

Taken together, the findings reconstruct a complete Glaserian progression from empirical incidents to conceptual theory. The process began with 10 information-rich participants situated in technological innovation and entrepreneurship and with no predetermined main concern or core category. Open coding produced 367 initial codes, which were progressively compared, reduced, and conceptualized into 70 main and subsidiary codes. Constant comparison enabled the identification of insufficient attention to technological literacy in engineering education as the main concern. Selective coding and theoretically directed comparison then shifted analytical attention toward the means through which that concern was addressed, allowing creative thinking, problem solving, teamwork, industrial experience, management capability, and economic capability to acquire significance as components of an emerging resolution process. Their conceptual integration yielded injecting technological literacy into engineering education as the core category. Theoretical saturation was reached when additional data ceased to substantially extend the properties, dimensions, or relationships of the relevant categories rather than when a predetermined numerical threshold had been achieved. Finally, theoretical coding established that the relationship among the developed categories was reciprocal and linkage-based, connecting personal, social, educational, and industrial environments. This final conceptual integration generated the Pendular Technological Curriculum in Engineering Education and illustrates, in practical terms, the defining Glaserian movement from substantive data to main concern, from main concern to core category, and from a developed core category to an integrated conceptual theory.

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4. Discussion and Conclusion

The present methodological tutorial was designed to clarify how Glaserian classic grounded theory operates in practice and to demonstrate the analytical movement from entry into a substantive area to the emergence of the main concern, development of the core category, theoretical sampling, theoretical coding, and final conceptual integration. The findings showed that methodological coherence in classic grounded theory depends less on the use of particular labels and more on maintaining an emergence-oriented logic throughout data collection and analysis. In the worked empirical illustration, the analysis began with the broad substantive area of engineering education and technological education rather than with a predetermined central phenomenon or explanatory framework. Open coding and constant comparison of the empirical materials gradually revealed insufficient attention to technological literacy in engineering education as the participants' main concern. Subsequent selective coding and theoretically directed analysis then demonstrated that this concern was addressed through a broader process conceptualized as injecting technological literacy into engineering education. Finally, theoretical coding indicated that the substantive categories were not organized through a simple linear sequence but through reciprocal linkages among personal, social, educational, and industrial environments, resulting in the formulation of the Pendular Technological Curriculum in Engineering Education. This trajectory illustrates the central Glaserian principle that theory should emerge progressively from conceptualized data rather than be produced by placing data within a predetermined analytical structure (Glaser, 1978, 1992).

One of the most important findings was the distinction between the substantive area, the main concern, and the core category. The substantive area of engineering and technological education provided the initial field of inquiry, but it did not determine what the participants' primary concern would ultimately be. Through open coding, concepts such as dominance of theoretical instruction, separation between university and industry, insufficient practical experience, weak real-world problem solving, and difficulty transforming disciplinary knowledge into technological action emerged from the empirical material. Their constant comparison led to the more abstract formulation of insufficient attention to technological literacy as the main concern. This finding is consistent with Connor et al., who emphasize that identification of the main concern is a defining analytical task in classic grounded theory and that the main concern should be discovered from what participants are repeatedly working to resolve rather than being equated with the initial topic of investigation (Connor et al., 2024). The result also corresponds with Glaser's original emphasis on asking what is occurring in the data and what participants are continually resolving rather than treating the researcher's initial questions as fixed analytical categories (Glaser, 1978). In this respect, the worked example demonstrates why a substantive topic, however important, cannot simply be renamed as the principal phenomenon or core category without an emergent analytical process.

The findings further indicated that the main concern and the core category are related but analytically distinct constructs. Insufficient attention to technological literacy represented the recurring problem evident across participants' accounts, whereas injecting technological literacy into engineering education represented the conceptual process through which that problem could be addressed. This distinction is highly consequential because classic grounded theory aims to explain how participants resolve or manage their main concern rather than merely describe the concern itself. Glaser argued that a core category should account for a substantial proportion of the variation in the data, relate meaningfully to other categories, and possess sufficient explanatory capacity to integrate the developing theory (Glaser, 1998). Holton and Walsh likewise describe the core category as the organizing conceptual center of classic grounded theory, around which selective coding, theoretical sampling, and theoretical integration become increasingly focused (Holton & Walsh, 2017). The present findings provide an applied demonstration of this principle: the core category did not emerge because it was the most frequent phrase in the interviews, but because it increasingly explained how diverse concepts such as creative thinking, problem solving, industrial experience, teamwork, management, and economic capability could be integrated as part of a common resolution process.

A further important result concerned the transition from open coding to selective coding. Initially, the data were analyzed broadly, and codes were not allocated to predefined categories such as causes, contexts, strategies, or consequences. Once the main concern had become conceptually apparent, however, the analytical focus narrowed toward data capable of developing the emerging core category. This movement is consistent with the

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Glaserian distinction between open and selective coding, in which selective coding is not a separate mechanical phase introduced at a predetermined point but a theoretically justified narrowing of attention around an emerging conceptual center (Glaser, 1998). This finding also supports the argument of Holton and Walsh that classic grounded theory progresses through increasingly focused conceptualization while retaining constant comparison as its central analytic mechanism (Holton & Walsh, 2017). The empirical illustration therefore helps clarify a frequent methodological misunderstanding: analytical focus in classic grounded theory should not be confused with forcing. Focus becomes legitimate when it emerges from previous analysis and is directed toward elaborating a developing core category rather than when it is imposed before the data have been adequately explored.

The findings also clarified the function of theoretical sampling. Initial participants were selected purposively because they possessed direct experience with invention, technology development, industrial activity, knowledge-based enterprise, and commercialization. At this early stage, theoretical sampling was not yet possible because no sufficiently developed category existed to direct subsequent sampling decisions. Once the main concern and related categories emerged, later data collection and documentary examination became increasingly oriented toward conceptual gaps identified through coding and memo writing. This result aligns with classical descriptions of theoretical sampling as a process driven by the developing theory rather than by demographic representativeness or a sampling plan fully specified before analysis (Glaser, 1978; Glaser & Strauss, 1967). Contemporary methodological discussions likewise emphasize that theoretical sampling is integral to category development in grounded theory and should be distinguished from purposive recruitment performed to enter a substantive field (Malone & Carmichael, 2025). Reviews of grounded theory applications have identified incomplete or unclear reporting of theoretical sampling as a recurring problem, reinforcing the importance of demonstrating how emerging categories actually influenced subsequent data collection (Ali et al., 2024; Connor et al., 2026).

The constant comparative method constituted another central finding of the reconstructed analytical process. The study generated 367 initial codes and 70 main and subsidiary codes, yet these numerical counts were not treated as indicators of theoretical adequacy. Instead, data were compared with data, codes with codes, codes with categories, and categories with other categories until increasingly abstract conceptual relationships were established. This is consistent with the foundational grounded theory position that conceptual development depends on systematic comparison rather than on simple aggregation or frequency counting (Glaser & Strauss, 1967). It also reflects Glaser's later emphasis that theoretical saturation occurs when additional data no longer contribute meaningful new properties or relationships to the relevant categories, rather than when a predetermined sample size or code count has been reached (Glaser, 1978). The present findings therefore reinforce the conceptual, rather than numerical, meaning of saturation. Although counts can transparently indicate the volume of coding activity, they cannot substitute for evidence that the properties and relationships of the developing categories have become sufficiently dense and stable.

Memo writing was similarly shown to be integral rather than supplementary to theory generation. Throughout the reconstructed analysis, memos documented comparisons, emerging conceptual ideas, unresolved relationships, and directions for further theoretical sampling. Their later sorting contributed directly to the recognition that personal, social, educational, and industrial environments were linked reciprocally. This finding aligns with Glaser's treatment of memos as a principal site of conceptual development and theoretical abstraction (Glaser, 1978). It also accords with Holton and Walsh's account of memo writing as the mechanism through which researchers move from substantive coding toward theoretical integration (Holton & Walsh, 2017). Importantly, the role of memos in classic grounded theory differs from a purely reflexive journal or procedural audit trail. Although reflexivity and methodological documentation may be useful, the primary purpose of Glaserian memoing is theoretical: to capture conceptual relationships while they are emerging and to preserve analytical ideas for subsequent sorting and integration.

The final stage of the analysis demonstrated the importance of theoretical coding. The findings did not support a straightforward linear causal model connecting educational deficiencies, interventions, and outcomes. Instead, the empirical materials indicated continuing reciprocal movement among personal, social, educational, and industrial environments. Industrial experience could introduce authentic problems into education; educational experiences could influence personal motivation and problem-solving capacity; social collaboration could shape

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the ability to engage in technological projects; and enhanced individual and collective competence could subsequently affect industrial participation. This reciprocal pattern led to the identification of "linkages" as the most appropriate theoretical code family and ultimately to the formulation of the Pendular Technological Curriculum in Engineering Education. This result closely reflects Glaser's conceptualization of theoretical coding as a means of identifying how substantive categories relate without forcing them into a single mandatory relationship structure (Glaser, 2005). Theoretical codes can represent processes, dimensions, strategies, interactions, linkages, cycles, or other forms of conceptual relationship depending on what the developed categories indicate. The present case therefore illustrates why theoretical coding should not be treated as synonymous with axial coding.

This distinction is especially important when comparing classic grounded theory with the Strauss–Corbin tradition. In the systematic approach, categories may be explicitly organized through relationships among causal conditions, phenomenon, context, intervening conditions, action or interaction strategies, and consequences (Corbin & Strauss, 2015; Strauss & Corbin, 1998). That structure can be highly appropriate when the research purpose is to construct a systematic explanatory model around such relationships. However, the present analysis showed that applying such a structure automatically to the worked empirical material would have produced a different analytic outcome from the one that emerged through the Glaserian process. The data supported reciprocal and pendular linkages rather than a fixed causal progression. This finding is consistent with Rieger's argument that different grounded theory traditions should be discriminated on the basis of their underlying logic, epistemological orientation, and analytical procedures rather than treated as interchangeable variants of the same method (Rieger, 2019). Cullen and Brennan similarly note that grounded theory encompasses distinct traditions whose divergences need to be understood explicitly if researchers are to maintain methodological coherence (Cullen & Brennan, 2021).

The findings also reinforce the distinction between classic grounded theory and constructivist grounded theory. Charmaz's constructivist approach explicitly emphasizes the co-construction of meaning, the situated nature of knowledge, and the interpretive role of the researcher (Charmaz, 2014). In contrast, the present tutorial reconstructed an analysis in which the methodological emphasis was placed on emergence of the main concern, conceptual relevance, constant comparison, and development of a core category explaining the resolution process. This does not imply that one tradition is methodologically superior to another. Rather, the finding supports the broader principle that researchers should align methodological claims with the analytical procedures actually used. Stough and Lee's review of grounded theory in educational research similarly demonstrated considerable variation in the implementation of grounded theory approaches and highlighted the need for greater specificity regarding methodological tradition (Stough & Lee, 2021). The present findings extend that concern by demonstrating how even closely related grounded theory traditions may generate different analytical trajectories from similar empirical material.

A similar distinction applies to thematic analysis. If the same dataset had been approached through reflexive thematic analysis, codes concerning theoretical dominance, university–industry separation, practical experience, and technological competence could plausibly have been organized into broader patterns of meaning concerning weaknesses in engineering education. Such an analysis could be rigorous and appropriate for a thematic research purpose. However, it would not necessarily require identification of a main concern, theoretical sampling, development of a core category, or theoretical coding. Braun and Clarke emphasize that thematic analysis should be conducted according to its own coherent methodological principles rather than through the uncritical combination of techniques drawn from other approaches (Braun & Clarke, 2022). Braun et al. further warn that good qualitative practice requires researchers to understand the assumptions and purposes of the analytical approach being used rather than assemble procedures eclectically (Braun et al., 2023). The present tutorial supports this position by showing that thematic organization and grounded theory generation represent different analytical objectives, even when they begin with similar coded materials.

The substantive empirical illustration also corresponded with earlier work concerning technological education and engineering curricula. Previous analysis of the evolution of technology and engineering education emphasized the growing need to connect theoretical engineering knowledge with technological capability, practical experience, creativity, problem solving, and interaction with industrial contexts (Bagherzadeh et al., 2017b). The grounded theory study from which the worked empirical materials were derived similarly demonstrated the importance of

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incorporating technological education into engineering curricula and conceptualized this integration through the experiences of individuals directly engaged in invention, technology development, and commercialization (Bagherzadeh et al., 2017a). The current methodological reconstruction does not seek to replicate or extend those substantive conclusions. Instead, the correspondence between the reconstructed analytical pathway and the published substantive findings strengthens the value of the case as a methodological illustration because it demonstrates how the eventual theoretical product can be traced back through open coding, conceptual comparison, the main concern, the core category, and theoretical integration.

More broadly, the findings support recent calls for greater methodological transparency in grounded theory research. Ali et al. identified variability in the use and reporting of grounded theory procedures and proposed the need for clearer methodological guidance (Ali et al., 2024). Connor et al. likewise showed that classic grounded theory studies may vary in their implementation of central components and emphasized the importance of methodological fidelity and transparent reporting (Connor et al., 2026). Methodological tutorials are particularly suitable for addressing such problems because they can explicitly connect abstract methodological principles with observable research decisions. Mbuagbaw et al. argue that methodological studies should report their design, analytical materials, rationale, and procedures with sufficient clarity to permit evaluation and application by others (Mbuagbaw et al., 2020). Yan similarly describes methodological tutorials as a useful article form when the objective is not simply to describe a method but to demonstrate how it should be implemented and reported in practice (Yan, 2020). The present study follows this logic by reconstructing not merely the final grounded theory but the decision pathway through which that theory became analytically defensible.

Taken together, the results indicate that the methodological integrity of Glaserian classic grounded theory rests on an interconnected sequence of emergent decisions rather than on isolated procedural terminology. A study becomes recognizably Glaserian when the substantive area remains analytically open, the main concern is allowed to emerge through constant comparison, the core category develops as an explanation of how that concern is resolved, selective coding and theoretical sampling are guided by the developing theory, saturation is judged conceptually, and theoretical coding integrates categories according to relationships supported by the data. This conclusion is consistent with the foundational distinction between emergence and forcing (Glaser, 1992), with the original formulation of grounded theory as an iterative strategy of theory generation (Glaser & Strauss, 1967), and with contemporary efforts to clarify how grounded theory should be selected, implemented, and evaluated (Cullen & Brennan, 2021; Malone & Carmichael, 2025). The worked example demonstrates that the value of classic grounded theory lies not in producing a predetermined type of model but in allowing the structure of the eventual explanation to develop from the conceptual relationships discovered in the data.

The present study has several limitations that should be considered when interpreting its methodological contribution. First, the empirical component was a reconstructed worked illustration based on an earlier qualitative investigation rather than a newly conducted grounded theory project designed specifically for this tutorial. Consequently, the reconstruction depended on the completeness and quality of the available interview notes, field notes, analytical memos, documentary materials, coding records, and previously developed conceptual model. Second, the empirical illustration involved only 10 participants drawn from a specialized group of entrepreneurial inventors, technology developers, innovative engineers, and knowledge-based business actors in electrical engineering, electronics, and computer engineering. Although numerical representativeness is not an objective of classic grounded theory, the narrow substantive context limits the range of situations through which the methodological process could be illustrated. Third, the interviews were not audio-recorded because of the sensitivity of technological and commercial information; although detailed notes were taken during interviews and expanded immediately afterward, some linguistic nuance and interactional detail may not have been preserved. Finally, presenting an iterative analytical process in a linear manuscript format inevitably simplifies the degree of overlap among coding, comparison, memo writing, theoretical sampling, saturation, and theoretical integration.

Future methodological research could extend this tutorial by prospectively documenting a classic grounded theory study from the first point of entry into the field through final theoretical integration, thereby permitting more detailed examination of how analytical decisions evolve in real time. Additional worked examples from different disciplines, participant populations, and data types would also be valuable for determining which aspects of the methodological pathway are stable across substantive areas

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and which require contextual adaptation. Comparative methodological studies could analyze the same qualitative dataset independently through Glaserian classic grounded theory, systematic grounded theory, constructivist grounded theory, and thematic analysis, making differences in coding decisions, sampling, category development, and final outputs directly observable. Future studies could also investigate how researchers judge the transition from open to selective coding, how theoretical sampling decisions are documented, and how theoretical saturation is operationalized in published research. Finally, methodological research could develop reporting checklists or audit frameworks specifically designed to evaluate the internal coherence of studies claiming to use Glaserian classic grounded theory.

Researchers intending to use Glaserian classic grounded theory should specify the methodological tradition explicitly at the design stage and ensure that subsequent analytical decisions remain consistent with its emergence-oriented logic. Initial interview questions should facilitate entry into the substantive area without functioning as predetermined coding categories, and researchers should distinguish clearly between purposive initial recruitment and later theoretical sampling. Coding records and memos should make visible how the main concern emerged, how alternative candidate core categories were considered, why analysis became more selective, and what conceptual gaps guided additional data collection. Reports should also explain saturation in terms of category development rather than relying only on the number of interviews or codes. Reviewers, supervisors, and journal editors can improve methodological quality by evaluating whether the stated grounded theory tradition aligns with the actual coding procedures, sampling logic, role of memos, integration strategy, and final theoretical product. Training programs should therefore place less emphasis on memorizing stage labels and greater emphasis on understanding the analytical decisions that connect raw data, constant comparison, the main concern, the core category, theoretical sampling, and theoretical integration.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

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All procedures performed in studies involving human participants were under the ethical standards of the institutional and, or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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