Transforming Declarative Knowledge into Procedural Skills: An Expert Accounting Teacher's Model for Solving Introductory Accounting Equations

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Abstract
This study addresses a key issue in introductory accounting education: the lack of focus on how declarative knowledge transforms into procedural skills to enhance learning efficiency. To contribute to this gap, the study models how an expert accounting teacher achieves skill mastery by transforming declarative knowledge into procedural skills when solving accounting equations, guided by the Adaptive Control of Thought-Rational (ACT-R) learning theory. ACT-R learning theory offers a framework for understanding how declarative memory evolves into procedural memory through spaced practice and repetition. Using a qualitative case study approach, this research focuses on a state-level expert teacher who solved 26 accounting transaction scenarios. Data were collected through document analysis and in-depth interviews, then analyzed thematically. From these solutions, 12 distinct transformation models were identified by transaction type. This paper focuses on two models—'Return of Purchased Inventory' and 'Accrued Expense'—selected for their clear illustration of cognitive differences between the teacher and her students. Findings reveal that the teacher progressed through six stages of knowledge compilation, reducing general-purpose production rules from 17 'if-then' steps to a single, highly efficient rule, demonstrating mastery. Notably, the teacher could also revert to the initial declarative stage when needed, reflecting her teaching adaptability. By establishing this transformation model as a cognitive benchmark, the study lays a foundation for future research comparing student learning models. Ultimately, it offers a cognitive perspective to address persistent learning challenges in accounting education, moving beyond traditional behaviorist approaches.
Keywords: Declarative Knowledge, Procedural Skills,Accounting Equations, ACT-R learning theory, Knowledge Compilation, Production Rules, Accounting Education

Introduction
The lack of teaching approaches in introductory accounting education that explicitly aim to improve students' learning and memory by differentiating between declarative knowledge

and procedural skills is identified as the core problem in this study. Where such practices do exist, they are often incidental rather than grounded in cognitive learning research, as reflected in the limited body of scholarly work addressing this distinction in accounting education (Herz, 1994; Herz & Schultz, 1999). Cognitive learning theory, rooted in cognitive psychology, highlights the importance of distinguishing between these two knowledge systems to enhance learning outcomes across various fields (Neisser, 2014; Sternberg & Sternberg, 2016). This distinction has been successfully applied in disciplines where optimizing learning and memory is essential (Dawson, 2022). However, as Herz and Schultz (1999) and Herz (1994) noted, accounting education has yet to formally integrate these cognitive learning principles or fully recognize the foundational role that both declarative knowledge and procedural skills play in effective learning.

This stands in stark contrast to fields such as language and mathematics, where the declarative/procedural model has been extensively researched and applied for decades (Ullman & Lovelett, 2018; Rittle Johnson et al., 2015; Long, 2005). In these disciplines, studies have progressed beyond merely recognizing the presence of declarative knowledge and procedural skills, exploring how their transformation can improve learning outcomes (Pili-Moss et al., 2020; Adeniji & Baker, 2022). In contrast, accounting education has largely overlooked these aspects, missing valuable opportunities to enhance learning efficiency by incorporating cognitive processes into its teaching approach (Herz & Schultz, 1999; Herz, 1994). Building on the ongoing challenges in improving accounting students' learning, as highlighted by accounting scholars, and the lack of cognitive learning insights in the field, this study identifies a key gap: the absence of attention to cognitive learning processes—specifically, the transformation of declarative knowledge into procedural skills—in enhancing accounting education. To address this, the study aims to explore the cognitive learning model used by an expert accounting teacher to transform declarative knowledge into procedural skills when solving accounting equations, drawing on the well-established ACT-R (Adaptive Control of Thought-Rational) learning theory. The ultimate aim is to use this idealized model as a foundation for improving her students' learning in future research and publications.

ACT-R describes the mechanisms underlying the acquisition of cognitive skills, providing a framework for understanding how knowledge transitions from initial learning to mastery (Anderson et al., 2021; Anderson et al., 2019; Tenison & Anderson, 2016; Tenison & Anderson, 2016; Tenison et al., 2016; Anderson et al., 2016; Anderson, 2007; Anderson, 2013; Anderson, 1982). This framework provides a robust foundation for understanding how declarative knowledge evolves into procedural skills, emphasizing the gradual reduction of cognitive effort as tasks become more automated and efficient (Gianferrara et al., 2024; Dimov et al., 2023; Seow et al., 2021; Anderson & Schunn, 2013; Whitehill, 2013).

Using a case study approach, this research employs document analysis and in-depth interviews with an expert teacher respondent to determine her model of transforming declarative knowledge into procedural skills when solving accounting equations. This approach lays the groundwork for a deeper understanding of how the ACT-R framework can inform and enhance accounting education (Anderson & Schunn, 2013; Whitehill, 2013). The expert teacher, rather than students, was selected to first establish an idealized model of cognitive skill acquisition. This model serves as a baseline for future comparisons with her students, which will be addressed in a subsequent publication. By adopting a gradual, step-

by-step approach, this study ensures a thorough exploration of the cognitive processes underpinning expertise before transitioning to comparisons with novice learners

Literature Review

This section begins by acknowledging the success of language and mathematics education in utilizing the declarative/procedural model to enhance learning outcomes, while highlighting its limited application in accounting education. It then transitions to a detailed exploration of the core components of ACT-R learning theory: declarative knowledge, knowledge compilation, and procedural skills. These components align with the three stages of cognitive skill acquisition—declarative, compilation, and procedural—demonstrating the progression toward mastery of accounting tasks in this study.

Language learning has long benefited from insights from cognitive psychology, which has been instrumental for decades in explaining, predicting, and guiding language acquisition and mastery among students (Esfandiari et al., 2020; Ullman & Lovelett, 2018; Hamrick, 2015). The declarative/procedural model has played a central role, with declarative knowledge encompassing vocabulary and grammar rules, while procedural knowledge supports skills such as sentence construction and fluency (Quam et al., 2018; Blockeel, 2015; Mbato, 2019). These knowledge systems do not operate in isolation but work together to facilitate language acquisition and use (Park & Kim, 2018; Westfechtel et al., 2019; Crosson, 2021). Declarative knowledge provides the foundational understanding of rules and facts about a language, while procedural knowledge enables the automatic application of these rules during real-time communication (Finn et al., 2016; Chen & Caldwell-Harris, 2019; Khatir, 2022). Recognizing the interaction between these knowledge systems is essential for designing effective teaching strategies and addressing challenges in language education (Watson et al., 2021; Tchesa & Shintani, 2024; Stefaniak et al., 2021).

Apart from language learning, the study of mathematics learning has historically been shaped by the interplay of conceptual knowledge (closely aligned with declarative knowledge) and procedural knowledge, with cognitive psychology providing a foundational framework (Maulina et al., 2020; Ghunaimat, 2024; Tchoshanov & Monarrez, 2024). Recent studies highlight the bidirectional and mutually reinforcing relationship between these forms of knowledge, moving beyond older paradigms that treated conceptual understanding as a prerequisite for procedural skill (Rittle-Johnson et al., 2015; Achmetli et al., 2019; Engelbrecht et al., 2017). Conceptual knowledge involves understanding mathematical principles and relationships, while procedural knowledge focuses on methods for solving problems (Gerasimova et al., 2023; Genareo et al., 2021; Qetrani & Achtaich, 2022). Some mathematics scholars emphasize that procedural tasks, when thoughtfully integrated, can lead to deeper conceptual insights rather than rote memorization (Lenz et al., 2024; Stovner & Klette, 2022; Bergsten et al., 2017). These studies advocate for instructional approaches that intertwine conceptual and procedural knowledge, fostering a more holistic understanding of mathematics (Hurrell, 2021; Zulnaidi & Zamri, 2017; Kusuma & Masduki, 2016).

However, the first significant attempt to emphasize the importance of declarative and procedural knowledge systems in accounting education was made by Professor Herz in 1994, followed by a subsequent publication in 1999 (Herz & Schultz, 1999). Since then, research in accounting education has largely lacked an in-depth exploration of these knowledge systems.

Most studies aimed at improving students' accounting knowledge and skills tend to focus on two distinct areas. One camp emphasizes enhancing students' conceptual understanding of accounting principles (Carstens et al., 2020; Zhou, 2019; Hillard & Sedaghat, 2021; Betakan et al., 2024; Lee et al., 2022; van Mourik & Wilkin, 2019), while the other focuses on balancing the development of technical accounting skills with soft skills such as communication and interpersonal abilities (Gunarathne et al., 2021; Kirstein et al., 2019; Smith et al., 2018; O'Shea et al., 2022; Edeigba, 2022; Abayadeera & Watty, 2016; Webb & Chaffer, 2016; Ebaid, 2021). In both approaches, the critical transition from declarative knowledge to procedural skills is often overlooked, treating these knowledge systems as separate and independent rather than as interconnected processes.

Building upon the identified gap, this study focuses on the accounting equation task as a representative framework to examine ACT-R learning theory's cognitive processes. The accounting equation task has long been recognized by accounting scholars as foundational, whether studied as part of the broader accounting cycle—where it serves as the initial step— or as a standalone element in rare cases (Bergner & Brooks, 2017; Lyman & Olvido, 2020; Zhang et al., 2020). Its significance lies in its utility for novice learners, serving as the bedrock for subsequent accounting lessons (Glover & Hwang, 2013; Joynt, 2022; Shanklin & Ehlen, 2017).The knowledge derived from mastering this task has ripple effects across future topics, supporting both procedural fluency and declarative reasoning such as critical thinking (Chiang et al., 2014; Boulianne, 2014; Zhou & Lamberton, 2021). However, mastery of the accounting equation task demands full proceduralization of knowledge, as evidenced in the fieldwork, which revealed lingering reliance on declarative processes among learners—one of the key motivations for this study.

Declarative knowledge refers to information about facts, concepts, steps, and sequences that can be consciously articulated and applied flexibly. In cognitive science, it is regarded as the foundation of learning, organized into interconnected units called chunks (Yang & Stocco, 2024; Augello et al., 2023). These chunks form mental networks that link related information, enabling deeper understanding and flexible recall. Within the ACT-R learning theory framework, declarative knowledge acquisition occurs through two symbolic learning processes: passive reception and active generation (Anderson & Schunn, 2013; Whitehill, 2013). Passive reception involves acquiring knowledge from external sources—such as lectures or readings—by intentionally memorizing and retaining the information. In contrast, active generation occurs when learners construct new knowledge through hands-on engagement, such as solving accounting equation tasks based on prior learning experiences.

Anderson, the founder of ACT-R, emphasized that while declarative knowledge of concepts and facts—such as understanding what sales, cash, or accounts receivable represent—should remain consciously accessible for flexible reasoning and adaptability, declarative knowledge of steps and sequences (such as solving accounting equation problems) should gradually transform into automatic procedures (Anderson et al., 2021, 2019; Anderson, 2007). This transformation process embeds those steps into procedural skills, allowing them to be executed with minimal conscious effort, thereby freeing cognitive resources for more complex or adaptive tasks. This study focuses on that transformation—the proceduralization of steps and sequences—given that mastery of accounting equation tasks relies heavily on sequential procedures becoming automatic. Understanding how this transition occurs is key

to improving instructional design and supporting students as they move from initial, effortful learning to more efficient, automatic performance.

Beyond symbolic acquisition of declarative knowledge chunks, subsymbolic learning determines how easily chunks can be retrieved (Anderson et al., 2021; Fisher et al., 2020). Each chunk has an activation level influenced by frequency and recency of retrieval, known as base-level activation (Moon et al., 2015; Ilbeygi et al., 2019). Additionally, associative activation—connections to current goals and context—enhances retrieval speed (Salvucci, 2021; Oh & Myung, 2012). However, associative priming alone is insufficient for complex tasks; consistent practice is essential to elevate base-level activation (Romero & Lebiere, 2015). This process aligns with the power laws of learning and forgetting, emphasizing that practice strengthens retrieval, while disuse weakens it over time (Dimov et al., 2020; Turner et al., 2016).

On the other hand, procedural knowledge refers to the "how-to" knowledge that guides actions and decision-making, enabling individuals to perform tasks and solve problems with increasing automaticity (Vasishth & Engelmann, 2021; Brasoveanu & Dotlačil, 2020; Gianferrara et al., 2024). Unlike declarative knowledge, which is consciously verbalized, procedural knowledge becomes embedded through practice, allowing tasks to be completed with minimal conscious effort (Park & Myung, 2013; Brüssow et al., 2013). In ACT-R learning theory, procedural knowledge is stored in the form of production rules—structured "IF-THEN" statements that guide behavior based on goals and contexts (Kim et al., 2019; Reiter-Haas et al., 2021). For example, an early production rule might state, "IF the goal is to increase an asset, THEN identify which account to debit," while a more refined rule condenses this to "IF the goal is to increase an asset, THEN debit the account."

Symbolic learning in procedural knowledge involves the creation of these production rules through analogy (Anderson & Schunn, 2013; Whitehill, 2013). Learners encounter goals and study solved examples, abstracting principles to form their own rules. The accuracy and clarity of instructional examples are critical, as flawed examples can lead to incorrect or inefficient production rules (Tenison & Anderson, 2016; Scheuerman et al., 2018).

Subsymbolic learning determines which production rules are selected and strengthened over time based on their utility (Anderson & Fincham, 2014; Fisher et al., 2022). Utility measures both success and efficiency. More refined, efficient rules are reinforced through repeated success and are selected more frequently in future tasks, while less effective rules are gradually phased out (Gianferrara et al., 2021; Park & Kim, 2018). This refinement process allows learners to transition from conscious, step-by-step effort to smooth, automated expertise, supporting faster and more accurate task execution with minimal cognitive load.

Knowledge compilation serves as the bridge that transforms declarative knowledge into procedural skill, enabling smoother and more efficient task execution (Neves & Anderson, 2013). In ACT-R, this process consists of two key mechanisms: composition and proceduralization (Whitehill, 2013; Anderson, 2007; Anderson, 1982). Together, they help transition explicit, step-by-step declarative instructions into automatic procedural actions. Composition involves combining sequences of production rules into single, streamlined rules (Anderson, 2007; Anderson, 1982). For instance, in accounting, an initial sequence of rules

might include "IF the goal is to increase an asset, THEN identify the appropriate account to debit" followed by "IF the account is identified, THEN apply the debit." Through composition, these rules merge into one: "IF the goal is to increase an asset, THEN debit the account." This reduction in steps speeds up task execution and simplifies the cognitive load.

Proceduralization further refines these composed rules by embedding the essential knowledge directly into the production rules (Anderson, 2007; Anderson, 1982). This removes the need to retrieve declarative knowledge from memory. For example, instead of requiring repeated reference to debit and credit rules, a proceduralized rule might directly state, "IF the goal is to record a cash sale, THEN debit cash and credit sales." This shift minimizes reliance on working memory and allows tasks to become almost automatic. By reducing cognitive effort and increasing efficiency, knowledge compilation enables learners to progress from deliberate, effortful processing to smooth, expert-level performance. It is this transformation—powered by composition and proceduralization—that makes procedural knowledge automatic, freeing cognitive resources for tackling more complex challenges.

Theoretical framework for modelling declarative/procedural transition
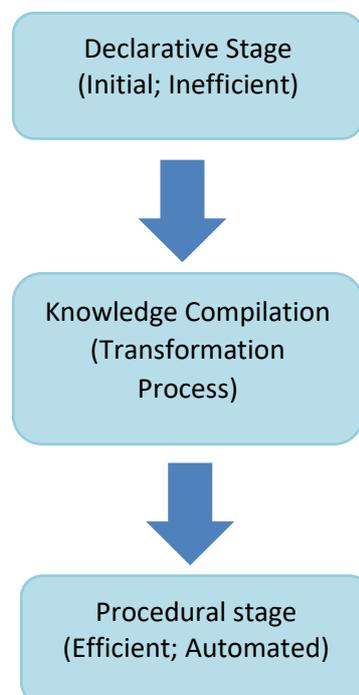
Source: John R. Anderson (2013)

The declarative stage represents initial learning, where knowledge is acquired in the form of declarative chunks. In this study, such knowledge includes the foundational facts and concepts of accounting—assets, liabilities, capital, income, and expenses—as well as the step-by-step sequences required to solve accounting equation tasks. At this stage, the knowledge is consciously applied, allowing flexibility and reducing errors. However, as learning progresses, the natural efficiency mechanisms of the learner's mind drive this knowledge toward proceduralization, ultimately transitioning to the procedural stage.

The procedural stage is where flexible declarative chunks evolve into production rules, expressed as "IF-THEN" statements, to achieve automaticity in task performance. This

automation not only enhances task efficiency but also allocates the learner's cognitive resources to more complex, flexible tasks requiring creativity and critical thinking. It represents a cognitive shift, optimizing the use of both declarative and procedural resources. The transformation from declarative to procedural knowledge is not instantaneous but occurs gradually through a process called knowledge compilation. This process has two key subprocesses: composition, which collapses sequences of production rules into single productions for efficiency, and proceduralization, which integrates factual knowledge directly into productions, removing the need for conscious retrieval.

In this study, the application of these stages is examined in the context of mastering two accounting equation tasks—'Return of Purchased Inventory' and 'Accrued Expense.' Detailed graphical representations of the transition from declarative to procedural stages for these tasks will be presented in the findings section, following the methodology.

Methodology

This study employs a qualitative research methodology, utilizing a case study approach to investigate the cognitive processes of an expert teacher within the framework of ACT-R learning theory. The fieldwork was conducted in a Malaysian high school, involving one teacher respondent and eight student respondents. However, as outlined in the abstract, this paper focuses exclusively on the findings related to the expert teacher respondent, reserving the comparison with her students for a subsequent publication.

Two primary data sources were utilized to achieve the study's objectives. The first source, labeled as document analysis, involved examining the teacher's solutions to 26 accounting transaction scenarios of varying complexity. These solutions were completed using a standard accounting equation template within an observed time frame of 15 minutes. The researcher maintained a non-intrusive stance throughout the observation to capture evidence of the teacher's procedural skills in their most natural and automatic form. According to ACT-R theory, procedural skills are expected to demonstrate high efficiency and near-automaticity, indicating the transformation of once-declarative knowledge into procedural knowledge through extensive practice and repetition. This phase is critical for identifying the degree of proceduralization achieved by the teacher.

The second source, in-depth interviews, was designed to capture the teacher's declarative knowledge. The teacher was asked to simulate teaching the task to first-time learners by providing a step-by-step verbal explanation of the accounting transaction scenarios. This process required deliberate articulation and conscious reasoning, expected to provide insights into her declarative knowledge. Declarative knowledge, in this context, is anticipated to reflect conscious, deliberate, and flexible reasoning, as opposed to the automaticity observed in procedural skills.

By combining these two data sources, this methodology seeks to capture both ends of the cognitive spectrum: declarative knowledge and procedural skills. This dual approach is particularly suited for exploring the transition from declarative knowledge to procedural skills, as theorized by ACT-R, ensuring a robust understanding of the teacher's cognitive processes. The research design is deliberately structured to align with the study's objective of modeling this transformation process.

Findings

The expert teacher's initial exposure to accounting equation-solving was similar to that of her students. However, through years of practice and experience, she has significantly surpassed them in terms of skill mastery. According to ACT-R learning theory, the declarative knowledge and its corresponding production rules used during this first-time learning phase are designed to be highly general, enabling the teacher to address any accounting equation task, regardless of the specific transaction. These general principles are outlined as follows:

Type: Applicable to all accounting transactions

Initial State:
Accounting equation: Asset = Liability + Capital − Drawing + Net Profit.
Identify all relevant accounts within categories (Assets, Liabilities, Capital, Drawing, Net Profit).
Action:
Input Values: Enter monetary amounts for the identified accounts (e.g., inventory returns, accrued expenses).
Modify Accounts: Record increases or decreases in the respective accounts as needed.
Check Balance: Verify whether the equation remains balanced after the changes.
New State:
Revised Equation: Show updated figures in the accounting equation, reflecting the monetary inputs and adjustments.
Equation Status: Determine if the total assets match the sum of liabilities and equity or pinpoint any imbalances.

Table 1: Declarative knowledge

If the goal is to complete a transaction analysis task, then identify the equation structure.
If structure identified as Asset = Liability + Capital − Drawing + Net Profit, then complete the task by recording all items and balancing with net profit/(loss).
If completing the task, then set a sub-goal to process each account.
If processing an account is complete, then record details and process the next account.
If identifying elements, then retrieve concepts of asset, liability, capital, and drawing with their effects.
If writing an element, then record its name, amount, and movement.
If asset increases, then record a positive value on the left.
If asset decreases, then record a negative value on the left.
If liability increases, then record a positive value on the right.
If liability decreases, then record a negative value on the right.
If capital increases, then record a positive value on the right.
If capital decreases, then record a negative value on the right.
If drawing increases, then record a positive value on the right.
If drawing decreases, then record a negative value on the right.
If totals match, then POP the goal with success.
If the left total exceeds the right, then record net profit as positive on the right and POP with success.
If the left total is less than the right, then record net profit as negative on the right and POP with success.

Table 2: Production Rules (17-rule)

Departing from this first-time instruction, ACT-R learning theory posits that the expert teacher can already begin interpreting this general declarative knowledge to handle specific accounting transactions (e.g., inventory sale, inventory purchase, asset acquisition, or expense recognition) with varying degrees of success—quarterly, partially, or fully. This study reveals that her mastery of these specific transactions progresses through five intermediary stages (via knowledge compilation processes of composition and proceduralization), from stage 1 to stage 5, before reaching stage 6, the most efficient and automated stage she currently employs. This evolution is shaped by repeated practice and the demands of teaching her students. As discussed in the preceding section, this study models the declarative stage, knowledge compilation stages, and procedural stage of the expert teacher using two selected transactions: **'Return of Purchased Inventory'** and **'Accrued Expense.'** The following visual representations illustrate these findings below:

Declarative Stage

Transaction 1:
Return of inventory worth $120, originally purchased by cheque for $1,200.
State (Initial):
Asset = Liability + Capital – Drawing + Net Profit
Assets: Inventory a/c identified; Bank a/c identified.
Action:
Assets: Decrease Inventory a/c by $120; Increase Bank a/c by $120.
New State:
Inventory a/c ↓ $120 + Bank a/c ↑ $120 = $0

Transaction 2:
Return of inventory worth $50, originally purchased by cash for $500.
State (Initial):
Asset = Liability + Capital – Drawing + Net Profit
Assets: Inventory a/c identified; Bank a/c identified.
Action:
Assets: Decrease Inventory a/c by $50; Increase Bank a/c by $50.
New State:
Inventory a/c ↓ $50 + Bank a/c ↑ $50 = $0

Stage 1 compilation (11 rules)

If the goal is to analyze a transaction, then identify the equation structure.

If identified as Asset = Liability + Capital – Drawing + Net Profit, then complete the task by recording all components, leaving net profit/(loss) as the balancing figure.

If a relevant account is processed, then document details and set a sub-goal for the next account.

If a return of purchased inventory is identified, then retrieve relevant knowledge from instruction.

If retrieving knowledge on inventory returns, then distinguish between cash and credit transactions.

If handling returns purchased with cash, then increase bank and decrease inventory.

If bank increases, then record the positive amount on the left side.

If inventory decreases, then record the negative amount on the left side.

If both sides balance, then terminate the goal with success.

If the left side exceeds the right, then record net profit as a positive amount on the right side and terminate with success.

If the left side is lower than the right, then record net profit as a negative amount on the right side and terminate with success.

Stage 2 compilation (9 rules)

If the goal is to analyze a transaction, then determine the appropriate equation structure.

If the structure is identified as Asset = Liability + Capital – Drawing + Net Profit, then complete the task by recording all components, leaving net profit/(loss) as the balancing figure.

If identifying a return of purchased inventory, then retrieve relevant knowledge from instruction.

If retrieving knowledge on inventory returns, then confirm whether the inventory was purchased with cash.

If purchased with cash, then increase bank and decrease inventory.

If recording these movements, then write the positive amount for the bank and the negative amount for inventory on the left side.

If both sides of the equation balance, then terminate the goal with success.

If the left side exceeds the right, then record net profit as a positive value on the right and complete the goal.

If the left side is lower than the right, then record net profit as a negative value on the right and complete the goal.

Stage 3 compilation (7 rules)

If the goal is to analyze a transaction, then determine the appropriate equation format.

If the format is identified as Asset = Liability + Capital – Drawing + Net Profit, then complete the task by ensuring all components are recorded, leaving net profit/(loss) as the balancing figure.

If identifying a return of purchased inventory, then confirm whether it was originally purchased with cash.

If purchased with cash, then adjust the equation by increasing the bank and decreasing the inventory.

If recording these adjustments, then write the positive value (bank) and the negative value (inventory) on the left side.

If checking the equation balance and both sides are equal, then terminate the goal successfully.

If the left side exceeds the right, then record net profit as a positive value on the right and complete the goal.

Stage 4 compilation (5 rules)

If the goal is to analyze a transaction, then determine the appropriate equation structure.

If the structure is identified as Asset = Liability + Capital – Drawing + Net Profit, then record all components, ensuring net profit/(loss) balances the equation.

If inventory purchased with cash is returned, then reduce inventory and increase the bank account accordingly.

If recording these adjustments, then input the positive value (bank) and the negative value (inventory) on the left side.

If the equation balances, then terminate the goal as successfully achieved.

Stage 5 compilation (3 rules)

If the equation is identified as Asset = Liability + Capital – Drawing + Net Profit, then conclude the task by recording all elements, with net profit/(loss) as the balancing figure.

If inventory purchased with cash is returned, then adjust by reducing inventory and increasing the bank account.

If adjustments are confirmed, then record the negative value for inventory and the positive value for bank on the left side and complete the goal successfully.

Stage 6 compilation (1 rule; procedural stage)
If inventory bought with cash is returned, then reduce inventory, increase bank, record the negative value for inventory on the left side and the positive value for bank on the left side, and successfully POP the goal.

On the other hand, for accrued expense transaction, the stages are visually represented as follows:

Declarative Stage

Transaction:
Salary expense accrued for $2,000.
State (Initial):
Asset = Liability + Capital − Drawing + Net Profit
Liabilities: Accrued Salary a/c identified.
Net profit: Identified.
Action:
Liabilities: Increase Accrued Salary a/c by $2,000.
Net Profit: Decrease net profit by $2,000.
New State:
$0 = Accrued Salary a/c ↑ $2,000 + Net profit ↓ $2,000.

Stage 1 compilation (11 rules)
If the goal is to complete a transaction analysis task, then determine the appropriate equation structure.
If identified as Asset = Liability + Capital − Drawing + Net Profit, then consider the task complete when all items are recorded, leaving net profit/(loss) as the balancing figure.
If a relevant account is processed, then record its details and set a sub-goal to process the next account.
If an expense element is identified, then retrieve relevant knowledge from instruction.
If retrieving knowledge on expenses, then distinguish between cash expenses and accrued expenses.
If focused on accrued expenses, then recognize it increases liabilities and decreases net profit.
If recording an increase in liabilities, then input the positive value on the right side.
If recording a decrease in net profit, then input the negative value on the right side.
If verifying equation balance and both sides are equal, then POP the goal as successful.
If the left side exceeds the right, then record net profit as a positive figure on the right and POP the goal successfully.
If the left side is less than the right, then record net profit as a negative figure on the right and POP the goal successfully.

Stage 2 compilation (9 rules)

If the goal is to complete a transaction analysis task, then determine the form of expression.

If identified as Asset = Liability + Capital − Drawing + Net Profit, then finalize the task when all elements are recorded, leaving net profit/(loss) as the balancing figure.

If an accrued expense is identified, then retrieve the corresponding knowledge from instruction.

If retrieving knowledge on accrued expenses, then recognize that it requires increasing a liability and reducing net profit.

If recording the liability increase, then enter the positive value for the liability on the right side.

If recording the net profit decrease, then enter the negative value for net profit on the right side.

If verifying the equation balance and both sides match, then POP the goal as successful.

If the left side surpasses the right, then record net profit as a positive figure on the right and POP the goal successfully.

If the left side is less than the right, then record net profit as a negative figure on the right and POP the goal successfully.

Stage 3 compilation (7 rules)

If the goal is to complete a transaction analysis task, then determine the appropriate form of expression.

If identified as Asset = Liability + Capital − Drawing + Net Profit, then finalize the task by ensuring all elements are recorded, leaving net profit/(loss) as the balancing figure.

If an accrued expense is identified, then acknowledge that it increases a liability and decreases net profit.

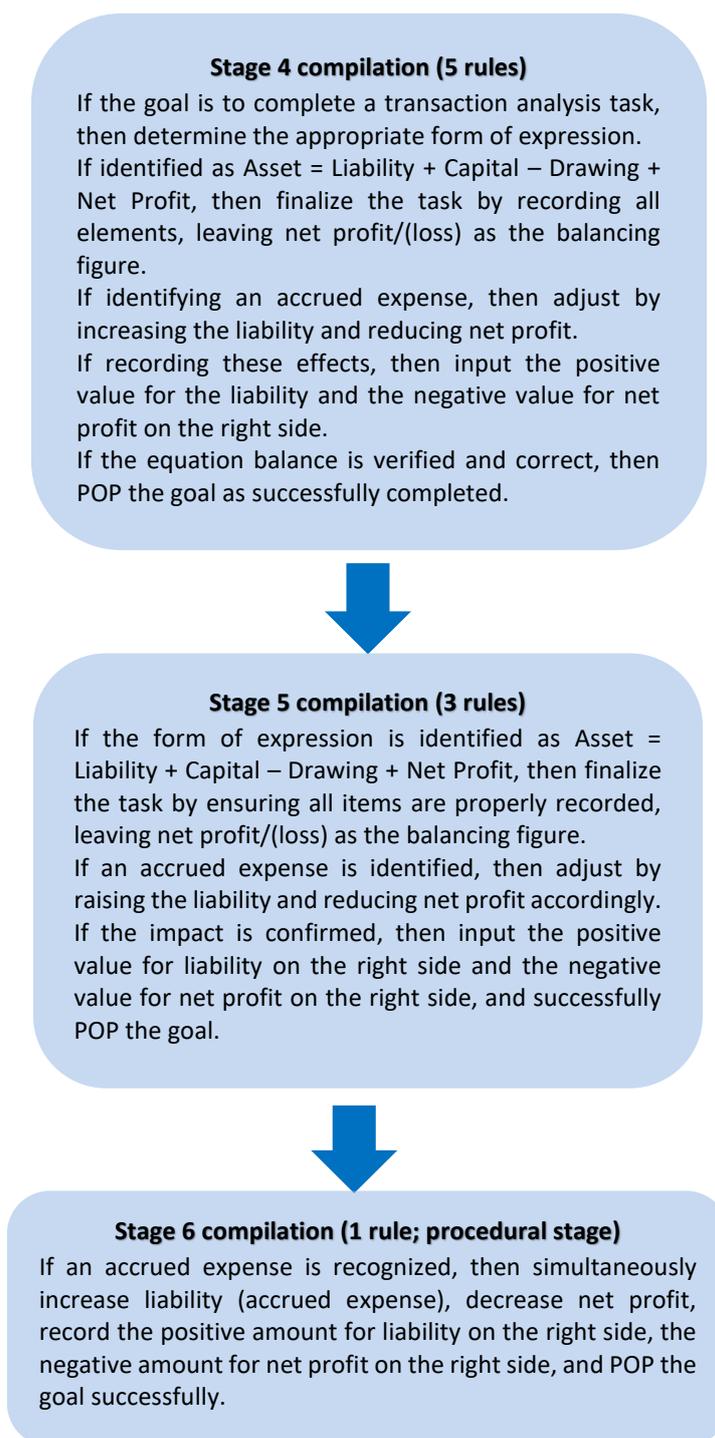If recording the liability increase, then document the positive value for the liability on the right side.

If recording the net profit decrease, then document the negative value for net profit on the right side.

If assessing the equation balance and both sides align, then POP the goal as successfully achieved.

If the balance does not align, then re-check entries for accuracy before completing the task.

Stage 4 compilation (5 rules)

If the goal is to complete a transaction analysis task, then determine the appropriate form of expression.

If identified as Asset = Liability + Capital – Drawing + Net Profit, then finalize the task by recording all elements, leaving net profit/(loss) as the balancing figure.

If identifying an accrued expense, then adjust by increasing the liability and reducing net profit.

If recording these effects, then input the positive value for the liability and the negative value for net profit on the right side.

If the equation balance is verified and correct, then POP the goal as successfully completed.

Stage 5 compilation (3 rules)

If the form of expression is identified as Asset = Liability + Capital – Drawing + Net Profit, then finalize the task by ensuring all items are properly recorded, leaving net profit/(loss) as the balancing figure.

If an accrued expense is identified, then adjust by raising the liability and reducing net profit accordingly.

If the impact is confirmed, then input the positive value for liability on the right side and the negative value for net profit on the right side, and successfully POP the goal.

Stage 6 compilation (1 rule; procedural stage)

If an accrued expense is recognized, then simultaneously increase liability (accrued expense), decrease net profit, record the positive amount for liability on the right side, the negative amount for net profit on the right side, and POP the goal successfully.

The findings in this section are well-supported by the data sources detailed in the methodology. From the document analysis (comprising 26 questions accurately and speedily solved by the expert teacher within just 15 minutes), the evidence highlights the degree of mastery the teacher has achieved. The researcher witnessed the task completion firsthand to validate its accuracy and timing, reinforcing the reliability of the findings. The teacher's performance aligns with the visual representations discussed in the theoretical framework, demonstrating stage 6 of the cognitive skill model. This stage represents a one-step action sequence for all transactions, including the two focused transactions of this study—'Return

of Purchased Inventory' and 'Accrued Expense.' This confirms that the expert teacher is operating at the full procedural stage, having left behind both the declarative stage and the five intermediary knowledge compilation stages as relics of her earlier learning process.

The in-depth interview findings further reveal the teacher's ability to articulate her thought processes in detail, despite her proceduralized mastery. This capability is attributed to her teaching profession, where she routinely transitions into a declarative mode of thinking to effectively instruct new cohorts of students. Such a skill enables her to consciously and deliberately verbalize the steps and sequences involved in solving accounting tasks, mimicking an initial declarative stage for the benefit of her learners. This study posits that this ability is unique to educators, as it requires deliberate practice in breaking down proceduralized knowledge into teachable components. In contrast, accounting practitioners outside academia are unlikely to possess this skill unless they are involved in training or mentorship roles, where similar demands for explicit articulation exist.

These findings highlight the unique cognitive demands placed on educators compared to non-educators. They suggest that the dual capability of achieving procedural mastery while retaining the ability to revert to declarative articulation is a defining feature of teaching professionals. This study also underscores the importance of such dual capability in shaping effective pedagogy, as it bridges the gap between the educator's expertise and the learner's initial stages of skill acquisition. In doing so, it provides valuable insights into how expert cognitive models can serve as benchmarks for designing instructional strategies that facilitate student learning and mastery in accounting education.

Conclusion

The application of ACT-R learning theory in accounting education offers a structured cognitive framework to enhance how students acquire, compile, and apply knowledge over time. The theory emphasizes the importance of differentiating between two types of learning tasks: declarative tasks, which require conscious reasoning, adaptability, and flexibility (such as understanding accounting concepts, principles, and frameworks), and procedural tasks, which rely on repeated practice and refinement to achieve automation (such as solving accounting equations or preparing journal entries). Declarative knowledge is best developed through active learning strategies, including discussions, case-based learning, and conceptual mapping, which help students build and reinforce rich associative networks. In contrast, procedural knowledge requires systematic, spaced, and repetitive practice to refine production rules, enabling tasks to be performed with speed, accuracy, and minimal conscious effort.

From a practical standpoint, ACT-R underscores the need to balance short-term credentialing—helping students pass assessments—and building long-term competence for professional readiness. Early-stage learning should utilize associative activation techniques such as mnemonics, analogies, and simulations, enabling students to form strong initial mental connections (Anderson & Schunn, 2013). However, this must be reinforced through spaced, distributed practice that increases base-level activation, ensuring knowledge remains accessible and usable beyond the classroom and into future, more complex tasks (Anderson & Schunn, 2013; Whitehill, 2013).

ACT-R also supports the power law of practice, highlighting how performance improves through repetition and refinement. Accordingly, accounting curricula should start with guided, structured exercises focused on credentialing outcomes, then transition toward more complex, open-ended tasks that encourage critical thinking, adaptability, and professional-level problem-solving. By integrating ACT-R's cognitive principles, accounting educators can effectively address persistent learning challenges, ensuring students develop both procedural fluency and conceptual depth—skills essential for lifelong competence in accounting practice.

This paper makes two major contributions. Firstly, it provides a theoretical contribution by addressing the existing scarcity of cognitive learning approach studies in accounting education, aiming to pave the way for future research in this area. It does so by applying ACT-R learning theory, thereby challenging the dominance of the traditional behaviorism approach. Secondly, it offers a methodological contribution by enriching the understanding of cognitive processes through a qualitative case study approach, in contrast to the prior ACT-R study in accounting education, which focused primarily on outcomes using quantitative correlation methods. The detailed description of thinking processes in this study provides greater potential for future practical applications.

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