frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 22 May 2025
DOI 10.3389/feduc.2025.1567329

OPEN ACCESS

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RECEIVED 27 January 2025
ACCEPTED 05 May 2025
PUBLISHED 22 May 2025

CITATION
Zhou Y, Javed K and Iveson J (2025) Addressing sophisticated misconceptions: an assimilation-based method for teaching accounting expenses.
Front. Educ. 10:1567329.
doi: 10.3389/feduc.2025.1567329

Addressing sophisticated misconceptions: an assimilation-based method for teaching accounting expenses

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Instructors often operate under the assumption that misconceptions stem from a preliminary, untutored, and pre-disciplinary context, leading them to traditionally adopt a refutational method inspired by the Piagetian principle of *accommodation* to address these naïve misconceptions. This research critiques the traditional refutational method, highlighting its problems in addressing sophisticated misconceptions embedded within a student's conceptual ecology. These problems include students' difficulty in abandoning their pre-existing conceptions, their struggle to initiate cognitive conflicts, and a loss of confidence for further learning due to disparity between prior understanding and new conceptions. This paper proposes an innovative solution rooted in the other Piagetian principle of *assimilation*, which leverages preconceptions as a foundation for initiating conceptual change. The study implements this innovative solution through a series of analogies organized in an assimilative sequence, where each analogy builds upon the previous one to correct specific misconceptions and establish a foundation for subsequent understanding. This approach enables students to become familiar with the case setting as they progress through the study of previous analogies and misconceptions, thereby enhancing their understanding when encountering subsequent analogies and misconceptions. This methodology is exemplified through an accounting educational case study involving five sequential analogies designed to rectify expense-related misconceptions. The successful classroom application of this assimilation-oriented method indicates its potential as a valuable framework for educational researchers and practitioners.

KEYWORDS

misconception, assimilation, accommodation, analogy, accounting education

1 Introduction

Misconceptions are defined as incorrect interpretations and understandings of concepts (Bahar, 2003; Bensley and Lilienfeld, 2015). The phenomenon of misconceptions has been extensively and multidimensionally documented within the education literature, illustrating that students often hold knowledge that conflicts with accepted scientific or disciplinary consensus (Verkade et al., 2017). In the course of their studies, students

typically possess preconceived beliefs or prior knowledge derived from their interactions with the natural and social environments (Eryilmaz, 2002). When these preconceptions accurately reflect the disciplinary context of reality, they can be utilized to enhance the absorption of new knowledge. Such preconceptions are referred to as anchoring conceptions and serve as a scaffold for the development of higher-level conceptual knowledge (Clement, 1993). Conversely, when preconceptions are incorrect or in conflict with disciplinary models of reality, they are termed misconceptions, leading to systematic patterns of errors in learning (Bensley and Lilienfeld, 2015; Verkade et al., 2017).

Misconceptions pose a significant barrier to the acquisition of new knowledge. The process of acquiring new information involves referencing an existing knowledge system, which comprises interconnected conceptual frameworks used to interpret experiences. Misconceptions are embedded within this prior knowledge system and generate misleading references to new information. This characteristic renders the task of overcoming misconceptions challenging, necessitating the active involvement of educators rather than relying solely on students' self-awareness. To address the issue of misconceptions effectively, educators must possess a profound understanding of these misconceptions within the disciplinary context before attempting to devise solutions (Gomez-Zwiep, 2008).

Instructors typically assume that misconceptions arise from a preliminary, untutored, and pre-disciplinary context, often dismissing them as naïve beliefs that obstruct scientific understanding (Osborne et al., 1993; Greca and Moreira, 2002; Byrne and Willis, 2014; Lucas and Mladenovic, 2009). Under this assumption of naïve belief, they traditionally employ a refutational approach to analyze and rectify misconceptions, arguing that poorly conceived knowledge is entirely erroneous and should therefore be criticized, refuted, and ultimately replaced by a more accurate understanding (Kowalski and Taylor, 2009; Verkade et al., 2017).

The refutational approach has constrained our comprehension of misconceptions and limited the potential for developing corrective solutions. Research indicates that misconceptions in higher education can arise during or after disciplinary instruction, even when students possess rudimentary elements of disciplinary knowledge (Sadler and Sonnert, 2016). These misconceptions are intricately intertwined with other knowledge schemas accurately perceived by students, rendering them so complexly embedded within the students' knowledge systems that they cannot be effectively addressed through a singular refutational treatment. This kind of misconceptions which are not naïve but sophisticated, are described as "difficult to identify, strongly held, and highly resistant to corrections through standard instruction" (Verkade et al., 2017, p. 3).

To conclude, our review highlights two critical gaps in the existing literature on misconceptions. The first gap is that previous research has largely centred on untutored or pre-disciplinary contexts, where students are expected to be novices or at an early stage of their studies, resulting in relatively simple misconceptions with minimal integration of knowledge components. However, the literature has rarely examined instructional contexts, where students have already gained foundational disciplinary knowledge, leading to more complex misconceptions that exhibit a greater level of integration among knowledge elements. Moreover, prior investigations have primarily utilized a refutational strategy influenced by Piaget's accommodation principle to address misconceptions by rejecting previous knowledge and wholly replacing it with new insights. In contrast, there appears to be a gap in the literature regarding the development of solutions that leverage Piaget's assimilation principle, which emphasizes the significance of students' pre-existing knowledge as a starting point for rectifying misconceptions.

In this research, we utilize Piaget's cognitive development theory (Piaget, 1928, 1977) to interrogate the conventional solution and propose a novel approach tailored specifically to address sophisticated misconceptions. Piaget's cognitive development theory focuses on the nature of knowledge and the processes by which humans acquire, construct, and utilize it. Piaget identifies two key processes in learning: assimilation and accommodation. Assimilation involves the reinterpretation of new information to fit into pre-existing cognitive schemas. During assimilation, learners rely on familiar or previously acquired knowledge to comprehend unfamiliar or new information. Conversely, the accommodation process entails modifying pre-existing schemas in response to new information. Accommodation, also referred to as "radical conceptual change" (Posner et al., 1982, p. 213), aims to create cognitive conflict, whereby the learner becomes dissatisfied with an initial conception, ultimately leading to its abandonment in favor of a new understanding (Hewson and Hewson, 1984; Oogarah-Pratap et al., 2020).

Unlike the traditional refutational approach, which relies on accommodation to address students' preconceptions, the new method we propose adheres to the principle of assimilation. This method utilizes preconceptions as a foundation to inform new conceptions, thereby correcting misconceived understandings. The assimilation-inspired approach developed in this paper integrates the principles of conceptual ecology with the technique of analogies. A practical model is formulated, comprising a series of analogous scenarios tailored to address sophisticated misconceptions that are interconnected and specific to a particular topic within learners' conceptual ecology. These analogies are sequenced in an assimilative manner, where each preceding analogy serves as the knowledge base for the subsequent one. Consequently, the correct understanding derived from resolving an earlier misconception becomes new knowledge, assimilated into the conceptual ecology, and serves as the preconception to address later misconceptions. This assimilative process results in a gradual yet continuous expansion of the conceptual ecology by systematically remediating misconceptions. The empirical context of this paper is the financial accounting discipline, demonstrating how the assimilative approach can be applied to overcome five interconnected and sophisticated misconceptions related to the topic of accounting expenses.

2 Literature review

2.1 Naïve misconceptions and the refutational approach

In the educational research literature, misconceptions are frequently conceptualized as naïve beliefs held by learners prior to their exposure to scientific and disciplinary instruction. These misconceptions are often pejoratively labeled as naïve

understandings and folk knowledge (Verkade et al., 2017), non-scientific beliefs (diSpezio, 2010), common-sense concepts (Halloun and Hestense, 1985), students' naïve explanations (Chi, 2005), children's ideas (Osborne et al., 1993), intuitive or naïve theories (diSessa, 2014), private versions of reality (Hashweh, 1988), and mental models (Greca and Moreira, 2002).

Accounting educators generally adopt this naïve belief view in misconception practices. For example, McGuigan and Weil (2011) contend that accounting misconceptions stem from students' preconceived, and frequently flawed, notions regarding the field of accounting. Byne and Willis (2014, p.156) describe accounting misconceptions as "incorrect subject-specific prior knowledge" and caution that such misconceptions "seriously impair students' understanding." Consistently, Lucas and Mladenovic (2009) maintain that misconceptions "appear to arise from everyday/intuitive understanding of accounting and rote usage or mimicry of accounting terms" (p.276).

Chi (2013) provides a more nuanced analysis of naïve misconceptions, categorizing them into four types: false beliefs, flawed mental models, category mistakes, and missing schema. False beliefs refer to incorrect individual ideas within the same dimension. A flawed mental model encompasses several naïve beliefs that collectively form an internal representation of a concept. Category mistakes occur when students fail to recognize differences between two categories. When a student has not conceived the existence of a category, this results in a missing schema. Chi (2013) argues that students persist in naïve misconceptions primarily due to their insufficient disciplinary knowledge. This framework has been effectively applied within accounting education.

diSessa (2017) conducts a comprehensive review of the literature on the conceptual change of naïve knowledge, leading to two theoretical claims that are destined to accommodation-led radical knowledge restructuring. The first claim is based on the coherence of naïve knowledge, as discussed by Carey (1985) 2009. It is argued that naïve or intuitive ideas are so broadly coherent and systematically intertwined that altering a single naïve idea would result in changes in others. The second claim, drawing on Chi (1992), concerns the ontology of naïve knowledge. It asserts that naïve ideas are ontologically impoverished because students lack the appropriate scientific ontology. Consequently, students with a non-scientific ontology may misinterpret instructed ideas (Chi, 1992; diSessa, 2017). Both claims reference Kuhn's (1970) concept of incommensurability, indicating that new theories cannot be interpreted within the framework of old theories. Therefore, it is essential to initiate "scientific revolutions" (Kuhn, 1970), wherein pre-instructional or naïve thoughts are discarded and replaced with scientific conceptions.

The aforementioned claims support the educational methodologies where educators, across various disciplines, typically endorse a refutational approach to rectify misconceptions. This refutational approach exemplifies the application of accommodation, aiming to achieve a fundamental restructuring of existing knowledge by discarding preconceptions and replacing them with new conceptions. It involves two phases: (1) generating cognitive conflicts against the unscientific preconceptions; and (2) refuting and replacing them with scientific conceptions (Kowalski and Taylor, 2004; Kowalski and Taylor, 2009; Verkade et al., 2017). For instance, assuming misconceptions exist prior to disciplinary intervention, Lucas and Mladenovic (2009) propose that accounting educators should construct a thorough explanation of the accounting concept that students misconceive, and then contrast disciplinary thinking with students' "everyday way of thinking" (p.277). Chi (2013) also advocates utilizing the refutational approach for various patterns of misconceptions. According to Chi (2013), a simple refutation can correct a false belief but cannot be directly applied to the other three patterns. Correcting flawed mental models is complex and involves refuting incorrect knowledge of different individual concepts. To correct category mistakes, refutation requires that students understand the differences between the two categories. Additionally, a missing schema must be introduced to students before refuting their misconceived knowledge.

2.2 Sophisticated misconceptions and the limitation of accommodation approach

In this section, we employ the conceptual ecology perspective to construct a nuanced understanding of misconceptions within the context of higher education. Unlike the traditional view, which categorizes misconceptions as purely naïve or entirely erroneous, we propose that some misconceptions are sophisticated, emerging during advanced stages of learning when students have acquired foundational disciplinary knowledge. In such cases, a student does not completely misunderstand a complex concept but possesses a correct yet limited understanding of it. A sophisticated misconception is distinct from a naïve understanding or untutored experience, as it arises in post-instruction, following standard disciplinary teaching. Moreover, although a sophisticated misconception may be incorrect, it is not merely a subjective interpretation or personal version of reality; rather, it is closely related to disciplinary or scientific explanations of the concept.

A conceptual ecology perspective, as proposed by Toulmin (1972), can offer valuable insights into the understanding of sophisticated misconceptions. A conceptual ecology encompasses a diverse array of cognitive schemas, which include past experiences, analogies, anomalies, epistemological commitments, and metaphysical beliefs. These elements collectively structure new knowledge. In essence, existing conceptions do not stand in isolation; rather, they are interconnected, forming an integrated knowledge system (Ozdemir and Clark, 2007; diSessa, 2014). From this perspective, both naïve and sophisticated misconceptions are rooted in pre-existing knowledge, but they arise in different contexts within the conceptual ecology. Naïve misconceptions stem from intuitive beliefs, where the learner's conceptual ecology lacks the disciplinary knowledge schemas. In contrast, sophisticated misconceptions develop within a conceptual ecology that has been enriched with accurate disciplinary conceptions. A sophisticated misconception is neither a naïve understanding arising from the learner's subjective judgment, nor a fragile construct derived from superficial reasoning. Instead, it is deeply embedded within the learner's conceptual ecology, intricately connected with other knowledge schemas that have been refined and substantiated through formal disciplinary study.

Misconceptions are a common phenomenon that can occur at any educational stage across various disciplines (Verkade et al., 2017). However, sophisticated misconceptions have been

infrequently discussed in prior literature. A few scholars (Barke et al., 2009; Sadler and Sonnert, 2016) have observed that misconceptions can emerge in the process of learning complex knowledge, especially in advanced courses, and refer to these as school-made misconceptions. These scholars acknowledge that school-made misconceptions differ from preconceptions held before entering a disciplinary study. Nonetheless, they often attribute school-made misconceptions to teachers' incorrect or insufficient subject-matter knowledge, focusing corrective efforts on enhancing the disciplinary knowledge of pre-service and in-service teachers. Sadler and Sonnert (2016, p.31) note that "a teacher without subject-matter knowledge may teach the concept incorrectly, and students may end up with the same incorrect belief as their teacher." Contrary to the assumption that teachers' knowledge is insufficient, this paper associates sophisticated misconceptions with students' conceptual ecology, which integrates correct disciplinary knowledge taught by teachers. Unlike previous studies that concentrate on preparing teachers with accurate disciplinary knowledge, this paper aims to explore a practical instructional method within the classroom to rectify sophisticated misconceptions through the lens of conceptual ecology. Consistently, Addido et al. (2022) indicate that employing the conceptual change model may be a successful strategy for tackling misconceptions and advancing conceptual understanding in the realm of science instruction.

The refutational approach based on Accommodation toward a radical restructure of knowledge is not always potent to any kind of misconceptions in any educational settings. As diSessa (2014, p.5) states, even students excelling in their disciplinary studies encounter "enduring misconceptions that traditional methods cannot overcome." Prior studies have documented three different phenomena where this traditional approach fails to achieve anticipated learning outcomes.

First, if a misconception is deeply entrenched within the student's existing knowledge schemas, the cognitive conflict necessary to challenge this existing knowledge is unlikely to occur. Consequently, students may show reluctance and unwillingness to abandon their pre-existing conceptions (Chan et al., 1997; Planinic et al., 2005). Secondly, students with lower intellectual abilities or insufficient knowledge capacity struggle to initiate cognitive conflicts. Even when such conflicts do arise, these students often lack the capability to comprehend and adopt the new conceptions as replacements (Limon, 2001; Zohar and Aharon-Kravetsky, 2005; Planinic et al., 2005). Thirdly, a significant disparity between preconceptions and new conceptions can lead to student frustration and a loss of confidence in further learning (Dega et al., 2013).

We draw on the conceptual ecology perspective to analyze the aforementioned three phenomenon concerning accommodation's limitations and rationalize the inadequacy of the traditional refutational approach to addressing sophisticated misconceptions. Revising a concept is not merely an isolated process; it involves revising all other concepts related to it (Posner et al., 1982). Accordingly, a through refutation of a highly intricate preconception may induce disproof of the well-established conceptual ecology, which includes not only the correct conceptions but also the learning and thinking approach upon which the learner depends. This results in the first phenomenon as to difficulty in creating cognitive conflicts against the misconceptions. Furthermore, the correct counterpart to the sophisticated misconception often involves complex pieces of knowledge that a student may not fully perceived in her conceptual ecology. When there is little or no connection between the new conception and the conceptual ecology, the unprepared learner may not endorse a sudden settlement of the new knowledge into the conceptual ecology. In such case, the learner would suffer various negative consequences in learning, including suspicion of the already acquired knowledge, an inability to capture the new knowledge (as per the second phenomenon), and discouragement from further study due to the unexpected gap between the new conception and their existing knowledge reserve (as per the third phenomenon).

2.3 Justification of assimilation to sophisticated misconceptions

In this section, we justify the application of assimilation in addressing sophisticated misconceptions through three primary considerations. The first consideration pertains to the knowledge-as-elements perspective, wherein conceptual change is facilitated by activating correct knowledge elements and eliminating erroneous ones. According to Ozdemir and Clark (2007, p.356), a student's existing knowledge system comprises "a collection of quasi-independent knowledge elements within a larger conceptual ecology that are loosely connected to a larger conceptual network without an overarching structure." The assimilation principle is thus pertinent to guiding the knowledge formation process, wherein quasi-independent knowledge elements can be integrated to "create more complex conceptual structures by adding new knowledge elements, . . ., and/or modify existing elements through an evolutionary process" (p.357). Similarly, Clark (2006) employs the concept of "facets" of knowledge to delineate an assimilation process in conceptual change, which involves the gradual enhancement of normative facets, the progressive diminution of non-normative facets, and the systematic integration of families of productive facets. A sophisticated misconception does not originate in a naïve or pre-instructional context; rather, it emerges from a relatively mature student's conceptual ecology, where misconceived knowledge coexists with foundational aspects of disciplinary knowledge. These correct disciplinary knowledge elements can serve as references to identify and eliminate the erroneous knowledge elements contributing to the misconception, as well as a foundation upon which new knowledge elements can be assimilated to establish a revised conception. In addition, Vosniadou (2019) examines the coexistence of intuitive understandings alongside scientific concepts, and underscores the significance of gradual learning to facilitate integration of new knowledge elements with pre-existing ones in science education.

The second consideration draws on the concept of phenomenological primitives (p-prims) as proposed by diSessa (1993, 2017). According to diSessa (2014), a student's conceptual ecology comprises nearly independent, small, and fragmentary structures known as p-prims. These p-prims encompass reasoning and intuitive threads that form the foundation of a conception, whether accurately understood or misconceived. diSessa (2014, P. 9) further elaborates that a conceptual ecology includes "coordinated classes" (concepts), "mental models," and other entities, with p-prims nested within these coordinated classes.

Similar to the knowledge-as-elements perspective, diSessa (2014, p. 12) asserts that "students possess rich conceptual resources (from their conceptual ecology) to draw, . . . which can or even must be utilized in developing scientific understanding." However, unlike the knowledge-as-elements perspective that seeks to identify and eliminate erroneous elements, diSessa (2014, 2017) contends that p-prims should not be construed as true or false. He argues that "whether instances of their use lead to valid claims and expectations or invalid ones is determined by their invisible and unknown (to subjects) conditions of activation and bindings" (2017, p. 19).

diSessa's (2014, 2017) argument reflects an assimilation process, wherein p-prims refined from a misconception can contribute to the formation of a scientific conception, provided they are properly activated or reorganized. At an advanced stage of learning, students have already developed some scientific reasoning frameworks, with which their sophisticated misconceptions are associated. These reasoning frameworks can be employed to assimilate new knowledge and reconstruct a new conception from the sophisticated misconception. For example, a study conducted by Juliyanto and Siswanto (2021) examined the impact of phenomenological primitives (p-prims) on students' cognitive capabilities and learning strategies in physics. The researchers discovered that students frequently relied on intuitive reasoning patterns, which could either facilitate or impede their comprehension of physical concepts, contingent on the manner in which these intuitive elements were engaged and scaffolded through instructional design. The study underscored the necessity of acknowledging these intuitive elements and leveraging them as initial points for instruction, rather than attempting to eliminate them altogether.

The third consideration pertains to the contexts or domains in which concepts are applied. Students frequently perceive a multifaceted concept accurately and apply it consistently within a specific context or domain. However, this consistency often fails to extend across broader domains due to the contextual sensitivity of cognitive structures and their associated cues (Hammer and Manz, 2019; Ozdemir and Clark, 2007). Consequently, scholars advocate for context-specific restructuring informed by assimilation rather than global restructuring through accommodation (Carey, 1999; Ozdemir and Clark, 2007). Naeem Sarwar et al. (2024) address the rehabilitation of misconceptions by conceptualizing the learning process as a transformative journey, similar to cognitive rehabilitation. They highlight the numerous interconnections between concepts and create a method that merges concept maps with conceptual change texts. This innovative approach is intended to enable learners to visualize the relationships among concepts, thereby promoting the removal of misconceptions.

The literature identifies two methods to address these context limitations. First, students can enhance their knowledge within a particular domain and gradually replace unscientific conceptions with scientific ones (Carey, 1999; Ozdemir and Clark, 2007). Second, students can refine accurate ideas and conceptual structures from a particular domain and then apply them to rebuild conceptions that are applicable across broader domains (diSessa, 2014, 2017; Hammer and Manz, 2019). A sophisticated misconception often adheres to a complex disciplinary knowledge claim that functions across various contexts or domains. The correct understanding and rich conceptual resources of a knowledge claim, developed within a specific context, can be utilized to overcome misunderstandings or misapplications of this claim in unfamiliar contexts.

3 The assimilative analogy method

Analogy or analogical reasoning is defined as "a means of describing or explaining unfamiliar concepts (or phenomena) by referring to another situation, which has similarities to the situation being considered" (Bryce and MacMillan, 2005, p.737). An analogy represents "a reworking of knowledge" (Ogborn et al., 1996, p.70), involving a base or foundational or prototypical concept derived from students' prior knowledge, and a target concept alluded from this existing knowledge. From this perspective, analogy is an application of the assimilation process, allowing "new material to be more easily assimilated with students' prior knowledge" (Jonane, 2015, p.57), thereby fostering a more scientific comprehension of the concept.

The literature has extensively explored the use of analogies in the learning of new concepts, emphasizing the importance of connecting new knowledge constructs with students' prior learning (Duit et al., 2001). Additionally, the enhancement of understanding abstract concepts has been facilitated through the use of concrete examples, detailed explanations, and visual presentations (Jonane, 2015). Despite the potential benefits, there is a notable lack of studies focused on using analogies to address misconceptions. For instance, Gentner (1983) explore how different analogies, such as comparing the flow of electricity to the flow of water or to crowds of people, can aid learners in correcting their misunderstandings about electrical circuits by offering more intuitive mental models. The current methodology for employing analogies is characterized by two distinct features. Firstly, instructors focus on specific knowledge points, utilizing one analogy to rectify one misconception. Secondly, the foundational analogy typically draws from pre-instructional conceptions or everyday experiences with which students are presumed to be intuitively familiar.

The traditional analogy-based instructional design predominantly facilitates the assimilation of isolated knowledge points, which are typically derived from intuitive experiences and lack interconnectivity. Under current methodologies, the application of analogies proves ineffective in addressing specific misconceived knowledge, particularly when comprehension of a relevant concept necessitates an accumulative understanding of multiple discipline-specific conceptions. In such scenarios, pre-instructional or intuitive understanding is inadequate for interpreting misconceived concepts situated at higher tiers within the hierarchical structure of disciplinary knowledge systems. This paper draws on the conceptual ecology perspective to develop a novel analogy method aimed at resolving clusters of correlated misconceptions rather than addressing individual misconceptions in isolation.

Figure 1 illustrates the application of assimilative analogies as a strategy to address a series of misconceptions that are both correlated and intricately intertwined with advanced disciplinary knowledge. This method is based on the assimilation principle

10.3389/feduc.2025.1567329

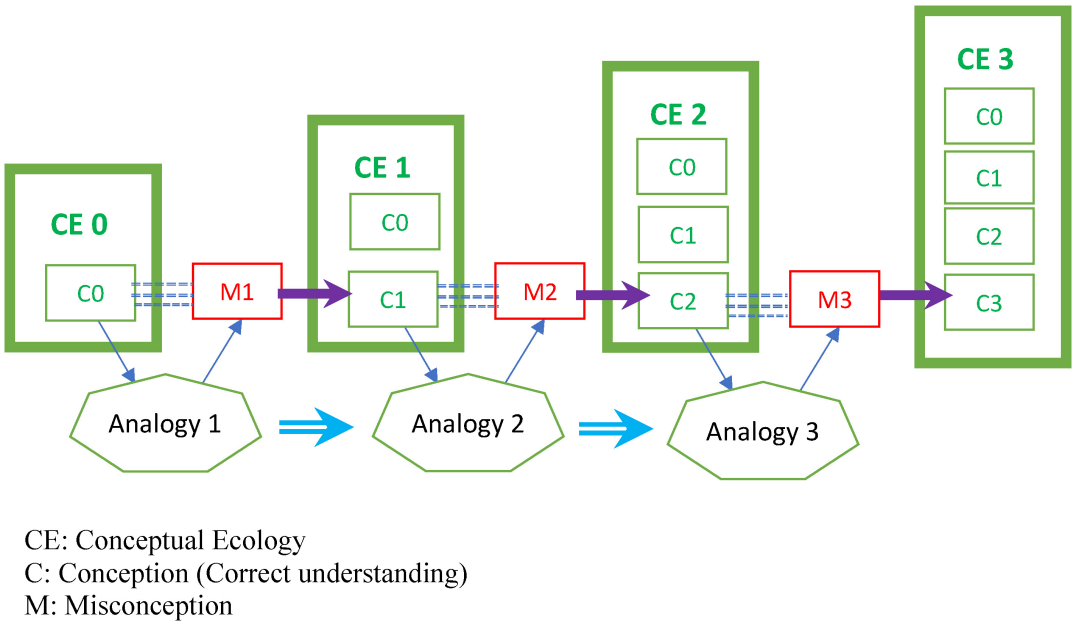

FIGURE 1
The model of assimilative analogies. CE, conceptual ecology; C, conception (correct understanding); M, misconception.

and conceptual ecology. It is posited that Conception 3 (C3) is dependent on Conception 2 (C2), which in turn is dependent on Conception 1 (C1). However, all these conceptions are erroneously understood as M3, M2, and M1, respectively. In such a scenario, it is improbable to achieve an accurate understanding of C3 through the conventional one-to-one analogy method when C2 and C1 remain misconceived.

We begin with Misconception 1 (M1), located within the learner's initial conceptual ecology (CE0), which comprises the existing knowledge base and accurate understanding pertinent to the target concepts (Vosniadou, 1994). From this foundational conceptual ecology (CE0), we identify a specific conception, or conceptions (C0), related to Misconception 1 (M1). Subsequently, we utilize C0 to develop an Analogy (1) aimed at rectifying M1.

When M1 undergoes rectification, it transforms into a new concept (C1) which is then integrated into the conceptual ecology, evolving into the first stage (CE1). Subsequently, C1 serves as the basis for Analogy 1, which leads to the formulation of Analogy 2, facilitating the transformation of M2 into C2. This new concept (C2) is then incorporated into the conceptual ecology, advancing it to the second stage (CE2). Similarly, by referring to C2, Analogy 3 is constructed to convert M3 into C3, which is subsequently absorbed into the conceptual ecology (CE3). Through the correction of M1, M2, and M3, the conceptual ecology (CE3) integrates three new concepts (C1, C2, and C3) compared to its original state (CE0). It is important to note that the interconnections between these concepts present an opportunity for instructors to design a series of analogies within a consistent scenario. This approach enables students to become familiar with the case setting as they progress through the study of previous analogies and misconceptions, thereby enhancing their understanding when encountering subsequent analogies and misconceptions.

Table 1 Expense-related misconceptions and correct conceptions.

Misconceptions	Conceptions (correct understanding)
M1: Acquiring (buying) an asset constitute an expense.	C1: Acquisition of a new asset does not constitute an expense; rather, it represents a reallocation of value from an existing asset, such as cash, to the newly acquired asset.
M2: Depreciation is not an expense.	C2: Depreciation is classified as an expense.
M3: Amortization is not an expense.	C3: Amortization is an expense.
M4: Prepayment is an expense.	C4: Prepayment is not an expense, but an asset.
M5: The Cost of Goods Sold (COGS) is not considered an expense. Alternatively, the cost of inventory is classified as an expense.	C5: The Cost of Goods Sold (COGS), as opposed to the cost of inventory, is classified as an expense.

4 A practical application of assimilative analogies in teaching accounting expenses

In this section, we present an educational case to illustrate the application of assimilative analogies as a method to address various misconceptions related to expenses in accounting education. Even though the concept of expenses is not inherently difficult for students to grasp, our observations from routine teaching practices indicate that students are generally equipped with a foundational knowledge base regarding expenses and related concepts. Nevertheless, it has been noted that students frequently struggle to identify certain specific expenses and often erroneously classify some non-expense transactions as expenses. Table 1 below

enumerates the common misconceptions alongside the correct conceptions.

Two key considerations justify the application of assimilative analogies. Firstly, students have already acquired foundational disciplinary knowledge pertaining to expenses and have correctly understood relevant concepts such as assets, depreciation, amortization, prepayment, and inventory. Therefore, it is unnecessary to reject and reconstruct the knowledge base using the accommodation or refutational approach. Secondly, we recognize the interconnections between these misconceptions, whereby the comprehension of certain concepts facilitates the understanding of others. Specifically, C1 supports C2 and C4, while C2 supports C3 and C5. This scenario presents an opportunity for the application of assimilative analogies, wherein a corrected misconception is transformed into both a new accurate conception and a foundation for rectifying the subsequent misconception. We present assimilative Analogies 1–5 as solutions addressing Misconceptions 1–5, respectively.

4.1 Analogy 1

Due to the influence of everyday language, students frequently confuse the term "expense" with "expenditure" (the act of spending money). To address this misconception, an analogy is employed that incorporates one base scenario and two target scenarios, demonstrating that spending money to acquire an asset does not alter the overall value of the assets.

Analogous scenarios	Description
Scenario 1 (base)	You bought a pen for $10 from a shop but never used it. Later, you returned the pen to the shop and got your $10 back.
Scenario 2 (target)	You bought a pen for $10 from a shop, but you didn't use it at all. Instead, you kept it locked in your drawer for the entire year.
Scenario 3 (target)	You bought a pen for $10 and used it throughout the year to write a novel. After completing the novel, you sold it to a publisher and earned revenue from the sale.
Instructional guide: Expense refers to sacrifice of an asset to generate revenue associated with that asset within the same accounting period. In Scenario 1, the act of "buying an asset" neither constitutes a sacrifice of assets nor generates revenue. In this instance, the total value of assets remains unchanged, as the $10 reduction in cash is offset by the addition of a pen value at $10 to the asset pen. Recognizing this point clarifies that an expense does not occur in Scenario 1 but rather in Scenario 2, where the pen is utilized to generate revenue.	

4.2 Analogy 2

Compared to payment expenses such as interest, rent, and taxes, which can be evidenced by cash outflows and invoices, depreciation is neither directly traceable from source documents nor reflected in cash flows, thereby making it challenging to perceive as an expense. Furthermore, M2 is also influenced by M1. Some students mistakenly consider the expense incurred from the payment made for acquiring the asset (M1) and, therefore, argue that the value decreased (depreciation) from the asset should not be recalculated as an expense. In this context, we employ C1 to eliminate the impacts of M1 on M2, and then utilize a specialized method to aid students in perceiving depreciation, which extends beyond straightforward observation.

Analogous scenarios	Description
Scenario 1 (base)	At the start of Year 1, you bought five pens for $10 each, totalling $50. Each year, you used up one pen to write a novel, so every year you had an expense of $10 for the pen you used.
Scenario 2 (target)	At the start of Year 1, you bought five regular pens, similar to those in a previous example. However, you quickly traded them in for one durable pen that cost $50. This durable pen can last for 5 years. The annual expense for this big pen was $10, which is the same amount you would have spent on one regular pen per year. This annual expense for the big pen is called depreciation.
Instructional guide: From Analogy 1 and C1, it is evident that the acquisition of five pens did not constitute an immediate expense. Each year, starting from Year 1, a single pen was utilized to generate revenue through writing activities. Consequently, the expense recognized each year is limited to the value of one pen, specifically $10. According to C1, the consumption of one pen per year is considered an expense in Scenario 2. If we conceptualize the five 1 year pens as a single "big pen" with a 5 years useful life, the annual depreciation expense of this "big" pen would be one-fifth of its total value. This results in an annual expense equivalent to that of one small pen in Scenario 2.	

4.3 Analogy 3

Amortization is referred as utilization of intangible assets to generate revenue, similar to depreciation of the fixed assets. Should students erroneously classify depreciation as an expense (M2) or fail to comprehend that assets can also be intangible, they would exhibit a misconception labeled M3. Analogy 3 is based on C2 and highlight equivalence between intangible assets and tangible (fixed) assets.

Analogous Scenarios	Description
Scenario 1 (base)	This scenario is the same as Analogy 2 Scenario 2 (target). At the start of Year 1, you bought five regular pens, similar to those in a previous example. However, you quickly traded them in for one durable pen that cost $50. This durable pen can last for 5 years. The annual expense for this pen was $10, which is the same amount you would have spent on one regular pen per year.
Scenario 2 (target)	At the start of Year 1, you bought a pen that would last for 5 years. However, you found out that the local government offered a typing service. The license to use this service for 5 years cost $50. So, you returned the pen and used the $50 refund to buy the typing service license. Now, instead of writing with a pen, you can just speak, and the typist will record your words.
Instructional guide: The target scenario in Analogy 2 serves as the base analogy for Analogy 3. Within Scenario 2, the license is classified as an intangible asset. The annual amortization of this license, amounting to $10 (which represents one-fifth of the license's value), is identical to the depreciation expense observed in Scenario 1, thereby constituting an annual expense.	

4.4 Analogy 4

The misunderstanding of prepayment as an expense (referred to as M4) can be attributed to three primary factors. Firstly, students who adhere to M1 often also subscribe to M4, as they equate expenses with expenditures, thereby misconstruing prepayments, which involve the spending of cash, as expenses. Secondly, students fail to grasp that prepayments contribute to future revenue; they do not recognize that an expense should correspond to the revenue generated from the consumption of related assets within the same accounting period, rather than revenue accrued in subsequent periods. Thirdly, students struggle to acknowledge prepayments as assets due to their significant divergence from the fixed and intangible assets with which they are more familiar. Analogy 4 encompasses three scenarios wherein we utilize C1 to illustrate that a prepayment does not constitute an expense and subsequently elucidate why it qualifies as an asset.

Analogous Scenarios	Description
Scenario 1 (base)	This scenario is the same as Analogy 1 Scenario 2. You bought a pen for $10 from a shop, but you didn't use it at all. Instead, you kept it locked in your drawer for the entire year.
Scenario 2 (bridge)	You bought a pen from a shop that offers a free storage service for some customers. You decided not to use the pen for a year, so you let the shop store it for you.
Scenario 3 (target)	You bought a pen from a shop, but it wasn't available for you to use during that year. You plan to collect the pen next year.
Instructional guide: Analogy 1 serves as the base scenario (1) in this analysis. We develop a bridge scenario, wherein a pen was purchased but retained by the shop. This bridge scenario transitions from the physical pen asset in the base scenario to the target scenario involving a non-physical prepayment. The uncollected pen (Scenario 3) is analogous to the unused pen stored in the shop (Scenario 2), which, in turn, is identical to the unused pen kept in the drawer (Scenario 1). In each case, the pen represents an asset that incurs no expense during the year, in accordance with Concept 1 (C1).	

4.5 Analogy 5

This misconception (M5) encompasses two aspects. Firstly, students often struggle to correlate the sale of inventory with the corresponding expense. Secondly, there is a common misunderstanding among students that the selling price of the inventory constitutes the expense. To address this, we utilize C2 (the depreciation expense) as the foundation for constructing Analogy 5.

Analogous Scenarios	Description
Scenario 1 (base)	This scenario is the same as Analogy 2 Scenario 1. At the start of Year 1, you bought five pens for $10 each, totaling $50. Each year, you used up one pen to write a novel, so every year you had an expense of $10 for the pen you used.
Scenario 2 (base)	This scenario is the same as Analogy 2 Scenario 2 about depreciation as an expense. At the start of Year 1, you bought five regular pens, similar to those in a previous example. However, you quickly traded them in for one durable pen that cost $50. This durable pen can last for 5 years. The annual expense for this big pen was $10, which is the same amount you would have spent on one regular pen per year. This annual expense for the big pen is called depreciation.
Scenario 3 (bridge)	You bought five pens for $10 each, spending $50 in total. Later, you sold one pen for $100. You recorded only the $10 cost of the pen as an expense, not the $100 you received from the sale. Therefore, you made a $90 profit (selling price $100 minus original cost $10), but only noted the $10 expense in your records.
Scenario 4 (target)	You initially had an inventory valued at $50, from which $10 worth of goods were sold, generating a revenue of $100. This $10 was Cost of Goods Sold (COGS), and is also considered an expense, similar to the pen sold in the bridge scenario. Cost of Goods Sold to inventory is analogous to the depreciation expense to an asset (Scenario 2).
Instructional guide: Analogy 5 involves two base scenarios drawn from Analogy 2. One base scenario applies to infer that the inventory sold (Goods Sold) is expensed to make revenue. And the other scenario is to elicit depreciation as a counterpart expense to Cost of Goods Sold.	

Figure 2 depicts the assimilative process that these analogies constitute in correcting the five correlated misconceptions about accounting expenses.

This instructional case illustrates application of assimilative analogies to rectify misconceptions which are interconnected and embodied in advanced disciplinary knowledge. The assimilation process initiates from the knowledge base C0, which encompasses a basic and normative understanding of expense concept and the other related concepts, including assets, depreciation, amortization, prepayment, inventory and cost of goods sold (COGS), which are linked to the target misconceptions.

Starting with C0, we design Analogy 1 to address Misconception 1 (M1), thereby achieving the corrected conception C1. This newly obtained C1 serves as the foundation for designing Analogy 2, which aims to resolve Misconception 2 (M2) and result in conception C2. Subsequently, Analogy 3 is developed with reference to C2 to correct Misconception 3 (M3), leading to conception C3. Unlike the sequential approach of the previous analogies, Analogies 4 and 5, which address Misconceptions 4 (M4) and 5 (M5), are not directly based on C3 but rather on the preceding conceptions (C1 and C2) and their associated analogies.

By employing this assimilation method, the five misconceptions are systematically corrected, culminating in the introduction of new conceptions C1 through C5 into the conceptual framework.

5 Instruction efficacy

To evaluate the instruction efficacy of the assimilative analogies, we utilized the convenience sampling method to recruit participants, who were students taking the introductory accounting course instructed by the researchers in the present

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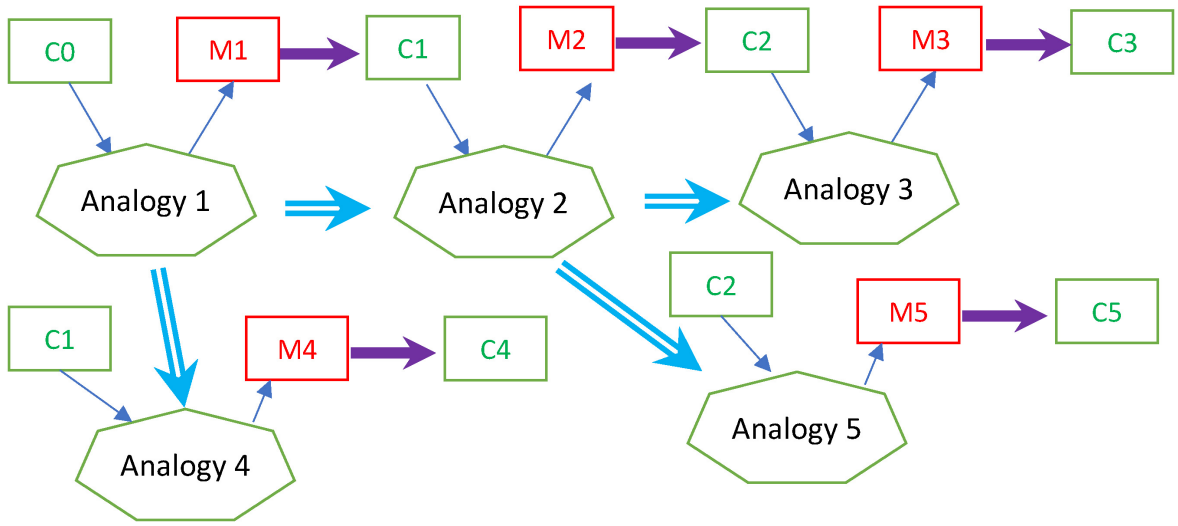

FIGURE 2
The assimilative analogies to correct the systematic expense-related misconception.

Table 2 Variations in scores.

Panel A: total scores						
		Pre-test (n = 93)	Post-test (n = 93)	Difference	Percentage increase	P-value (two-tailed)
Mean score		1.237	3.312	2.075	168%	< 0.001
Panel B: scores for individual questions						
Test item	Conceptions	Pre-test mean score (n = 93)	Post-test mean score (n = 93)	Increase	Percentage increase	P-value (two-tailed)
1	C1 and C2	0.5269	0.9247	0.3978	75%	< 0.001
2	C3	0.3763	0.9355	0.5592	149%	< 0.001
3	C4	0.2473	0.7957	0.5484	221%	< 0.001
4	C5	0.0860	0.6559	0.5699	663%	< 0.001

Table 3 Variations in certainty.

Test item	Conceptions	Pre-test	Pre-test	Pre-test	Post-test	Post-test	Correct answers in both pre-test and post-test
		Correct answers (n = 93)	Correct answers with certainty (n = 93)	Correct answers with uncertainty (n = 93)	Correct answers (n = 93)	Correct answer with certainty (n = 93)	Transition from uncertainty to certainty
1	C1 and C2	49	36	13	76	68	From 13 to 13 (100%)
2	C3	35	19	16	77	67	
							From 16 to 16 (100%)
3	C4	23	9	14	64	55	From 14 to 14 (100%)
4	C5	8	4	4	58	43	From 4 to 4 (100%)

study. Data were collected from 93 students across three teaching terms conducted in 2023 and 2024 at an Australian tertiary institution to evaluate the effectiveness of assimilative analogies. Each term included a tutorial designed to implement the learning intervention, with students expected to possess basic accounting knowledge following the completion of the introductory accounting unit.

During the tutorial session, two assessments were administered. The initial assessment consisted of four items designed to evaluate students' comprehension of five distinct expense concepts.

Specifically, the first question addressed concepts C1 and C2, while the remaining three questions pertained to concepts C3, C4, and C5, respectively. Each correct response on the pre-test was awarded one mark, with no marks allocated for incorrect answers. Similarly, the post-test assessed students' understanding of the same expense topics, with one mark given for each correct response and no marks awarded for incorrect answers.

To account for the potential of students guessing the correct answer, three self-report options are provided for each test item in both the pre-test and post-test. These options are: "I confirm my answer," "I reasonably guess this answer," and "I know little or nothing about it (thus, no answer is provided for the question)." These choices reflect different levels of self-assessment concerning certainty, uncertainty, and lack of knowledge.

We acknowledge the presence of internal validity threats, which include testing threats and scoring bias threats that may occur during the evaluation. Especially, inconsistent measurement tools, such as differing levels of difficulty in pre/post-tests, or biases in scoring can compromise the integrity of the evaluation outcomes. To mitigate these internal threats, we utilize parallel pre/post-tests that maintain consistent difficulty and content, thereby addressing testing or instrument-related concerns. Furthermore, to diminish scoring bias, we design the pre-test and post-test using multiple-choice questions with predetermined correct answers, which helps to limit subjective evaluations by markers. We also implement blind scoring methods to grade the tests, ensuring that post-test assessments are performed without awareness of pre-test results.

The initial evaluation indicated that students achieved an average of 1.237 correct responses (Table 2, Panel A). Following instructional intervention, students exhibited improvement, attaining an average of 3.312 correct responses in the subsequent assessment. Statistical analysis using a paired-sample t-test revealed a significant difference between the mean scores (p-value < 0.001).

The pre-test results presented in Table 2 Panel B illustrate the varying degrees of complexity among the four conceptions, as evidenced by the mean scores, which range from 0.5269 correct items to 0.0860 correct items. These findings corroborate our understanding of the complexity hierarchy inherent to the targeted conceptions. Additionally, the complexity hierarchy is further substantiated in Table 3, which demonstrates a decline in both the number of students providing correct responses and the number of students confirming these correct responses for the four test items. Notably, Conception 4 emerges as particularly challenging for accounting students, with fewer than 10% of students offering correct answers, and less than 5% affirming their accuracy in the pre-test.

In addition, we carried out separate paired t-tests for each of the individual test items as presented in Table 2 Panel B. The average score showed an improvement for each test item, and this improvement was found to be statistically significant for all test items (with a p-value of less than 0.001 for all five questions).

Separate paired t-tests were conducted for each individual test item, as detailed in Table 2 Panel B. The results demonstrated an average score improvement across all test items. This improvement was statistically significant for each test item, with p-values less than 0.001 for all five questions.

Table 3 indicates a marked increase in the number of participants who expressed certainty in their correct responses from the pre-test to the post-test across all test items. This rise in certainty implies that the intervention or educational process was successful not only in enhancing the accuracy of responses but also in elevating the participants' confidence in their knowledge. Notably, all those students (100%) who have provided correct answers but expressed uncertainty in any test item in the pre-test exhibited certainty in their correct responses for the corresponding test item in the post-test.

To summarize, before the intervention, a significant portion of students lacked comprehension on various concepts, despite possessing some prior knowledge. According to the students' feedback, the assimilative analogy intervention proves to be effective in enhancing the learning of these concepts. This intervention either rectifies misconceptions or fortifies accurate comprehension. It is noteworthy that the effectiveness of the intervention is not uniform across all concepts. There was a marked improvement in the comprehension of concepts C1, C2, and C3. However, fewer students reported understanding concepts C4 and C5 post-intervention. Furthermore, a significant number of students continued to experience difficulty or a lack of understanding regarding these two relatively complex concepts.

The students were provided with the opportunity to deliver either oral or written feedback. Some students submitted comments that included a mixture of both positive and negative critiques, which are subsequently presented for enhanced comprehension.

5.1 Positive feedback

I used to think that spending money always meant it was an expense. But then I learned that's not always true. Now I know that buying an asset is not an expense, and then a prepayment is not an expense too. Interesting.
I know what expenses are and can usually figure them out. However, I often overlooked special expenses like Depreciation and Cost of Inventory Sold. Understanding these through examples (analogies) has helped me avoid mistakes in my bookkeeping.
I was not so familiar with intangible assets and amortization. Analogy 3 offers something new for me to learn the two concepts by comparing intangible assets to fixed assets, and amortization to depreciation.
Even though I made no mistake in the test, I still found analogies to be beneficial. They solidify my understanding of the topics.

5.2 Negative feedback

Analogies 4 and 5 are initially challenging to understand. However, with some additional review, they become easier to grasp.
Regarding C5, I realized that a prepayment is not an expense. But I am still unsure why it is classified as an asset.
Analogies serve to simplify these ideas by providing an overview. But they may not fully explain complex conceptions in detail, like C4, in detail.

The positive feedback corroborates the results of the paired *t*-test analysis, underscoring the general satisfaction with the assimilative analogies. According to the feedback, these analogies provide a structured framework that leverages familiar knowledge, thereby enhancing students' existing understanding and increasing their confidence in acquiring new knowledge. However, the negative comments indicate that students faced greater difficulties in comprehending concepts C4 and C5. Compared to the initial three concepts, students reported a less favorable learning experience with the latter two.

Misconceptions corresponding to C4 and C5 are typically sophisticated, as Ozdemir and Clark (2007, p.352) characterize them as "highly resistant to change," "attached to other concepts" and "not independent from cognitive artifacts within a learner's conceptual ecology." For learners to accept the conclusions associated with these complex conceptions, they must "reach a particular level of cognitive maturity" (Reinking et al., 2002, p.113). The scope of knowledge for C4 and C5 extends beyond the topic of expenses, which includes C1, C2, and C3, to encompass additional topics such as inventory accounts, prepayments, income, the historical cost assumption, and the accrual principle. Although these related knowledge schemas are intended to be introduced prior to the tutorial, it is possible that students may not be adequately prepared in these areas. Consequently, such students are likely to face challenges when integrating C4 and C5 into their conceptual framework. To address this limitation, it is essential to provide ample supplementary instructions regarding these external schemas that are connected to the target conceptions.

6 Conclusion

Literature has traditionally focused on naïve misconceptions and rectified them through the refutational approach adhering to the Piagetian principle of accommodation (Kowalski and Taylor, 2009; Verkade et al., 2017). However, it is argued that this traditional approach is inadequate for overcoming sophisticated misconceptions, which are deeply embedded within a student's conceptual ecology and involve intricate and interrelated knowledge schemas (diSessa, 2014; Hammer and Manz, 2019).

To address this knowledge gap, this research explores an alternative solution drawing on the other Piagetian principle – assimilation. According to Piaget, (1928, 1977), assimilation involves using preconceptions as a foundation to initiate conceptual change, in contrast to the traditional approach that favors a thorough disproof. This innovative solution is realized through a series of analogies organized in an assimilative sequence. In this structure, each preceding analogy not only serves to rectify a specific misconception but also establishes a foundation for understanding the subsequent analogy, thereby addressing the next misconception. Through this process, the conceptual framework undergoes gradual development, facilitating the resolution of interconnected thematic misconceptions in a step-by-step manner.

The application of this assimilation-based methodology is exemplified in an accounting case study, where five sequential analogies are deliberately designed to rectify a series of expense-related misconceptions. The successful classroom application of this assimilation-based method indicates its potential as a valuable framework for educational researchers and practitioners. It can apply to the instruction of other accounting topics and other management disciplines that involve complex misconceptions, thereby enhancing pedagogical strategies in these fields.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

YZ: Conceptualization, Formal Analysis, Investigation, Methodology, Writing – original draft. KJ: Data curation, Project administration, Resources, Writing – review and editing. JI: Funding acquisition, Software, Supervision, Writing – review and editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research has received financial supports from the ASA Institute of Higher Education, Australia.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Addido, J., Burrows, A. C., and Slater, T. F. (2022). Addressing pre-service teachers' misconceptions and promoting conceptual understanding through the conceptual change model. *Prob. Educ. 21st Century* 80, 499–515. doi: 10.33225/pec/22.80.499

Bahar, M. (2003). Misconceptions in biology education and conceptual change strategies. *Educ. Sci.* 3, 55–64.

Barke, H., Hazari, A., and Yitbarek, S. (2009). *Misconceptions in Chemistry*. Cham: Springer.

Bensley, D. A., and Lilienfeld, S. O. (2015). What is a psychological misconception? Moving toward an empirical answer. *Teach. Psychol.* 42, 282–292. doi: 10.1177/0098628315603059

Bryce, T., and MacMillan, K. (2005). Encouraging conceptual change: The use of bridging analogies in the teaching of action-reaction forces and the 'at rest' condition in physics. *Int. J. Sci. Educ.* 27, 737–763. doi: 10.1080/09500690500038132

Byrne, M., and Willis, P. (2014). "The role of prior accounting education and work experience," in *The Routledge Companion to Accounting Education*, ed. R. Wilson (London: Routledge), 145–162.

Carey, S. (1985). *Conceptual Change in Childhood*. Cambridge, MA: The MIT Press.

Carey, S. (1999). "Sources of conceptual change," in *Conceptual development: Piaget's legacy*, eds E. K. Scholnick, K. Nelson, S. A. Gelman, and P. H. Miller (Mahwah, NJ: Lawrence Erlbaum Associates Publishers), 293–326.

Carey, S. (2009). Where our number concept come from. *J. Philos.* 106, 220–254. doi: 10.5840/jphil2009106418

Chan, C., Burtis, J., and Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceptual change. *Cogn. Instruct.* 15, 1–40. doi: 10.1207/s1532690xci1501_1

Chi, M. (1992). "Conceptual change within and across ontological categories: Implications for learning and discovery in sciences," *Cognitive models of science: Minnesota studies in the philosophy of science*, ed. R. Giere (Minneapolis: University of Minnesota Press), 129–186.

Chi, M. T. H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *J. Learn. Sci.* 14, 161–199. doi: 10.1207/s15327809jls1402_1

Chi, M. T. H. (2013). "Two kinds and four sub-types of misconceived knowledge, ways to change it, and the learning outcomes," in *International Handbook of Research on Conceptual Change*, ed. S. Vosniadou (New York, NY: Routledge Press), 49–70.

Clark, D. B. (2006). Longitudinal conceptual change in Students's understanding of thermal equilibrium: An examination of the process of conceptual restructuring. *Cogn. Instruct.* 24, 467–563. doi: 10.1207/s1532690xci2404_3

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *J. Res. Sci. Teach.* 30, 1241–1257. doi: 10.1002/tea.3660301007

Dega, B. G., Kriek, J., and Mogese, T. F. (2013). Students' conceptual change in electricity and magnetism using simulations: A comparison of cognitive perturbation and cognitive conflict. *J. Res. Sci. Teach.* 50, 677–698. doi: 10.1002/tea.21096

diSessa, A. (1993). Toward an epistemology of physics. *Cogn. Instruct.* 10, 105–225. doi: 10.1080/07370008.1985.9649008

diSessa, A. (2014). "A history of conceptual change research: Threads and fault lines," in *The Cambridge Handbook of the Learning Sciences*, 2nd Edn, ed. R. Sawyer (Cambridge: Cambridge University Press), 88–108. doi: 10.1017/CBO9781139519526.007

diSessa, A. (2017). "Knowledge in pieces: An evolving framework for understanding knowing and learning," in *Converging Perspectives on Conceptual Change*, eds T. Amin and O. Levrini (London: Routledge), 9–16. doi: 10.4324/9781315467139-3

diSpezio, M. (2010). Misconceptions in science classroom. *Sci. Scope* 34, 16–21.

Duit, R., Roth, W., Komorek, M., and Wilbers, J. (2001). Fostering conceptual change by analogies – between Scylla and Charybdis. *Learn. Instruct.* 11, 283–303. doi: 10.1016/S0959-4752(00)00034-7

Eryilmaz, A. (2002). Effects of conceptual assignments and conceptual change discussions on students' misconceptions and achievement regarding force and motion. *J. Res. Sci. Teach.* 39, 1001–1015. doi: 10.1002/tea.10054

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cogn. Sci.* 7, 155–170. doi: 10.1207/s15516709cog0702_3

Gomez-Zwiep, S. (2008). Elementary teachers' understanding of students' science misconceptions: Implications for practice and teacher education. *J. Sci. Teach. Educ.* 19, 437–454. doi: 10.1007/s10972-008-9102-y

Greca, I., and Moreira, M. (2002). Mental, physical, and mathematical models in the teaching and learning of physics. *Sci. Educ.* 86, 106–121. doi: 10.1002/sce.10013

Halloun, I., and Hestense, D. (1985). Common sense concepts about motion. *Am. J. Phys.* 53, 1056–1065. doi: 10.1119/1.14031

Hammer, D., and Manz, E. (2019). Odd ideas about learning science: A response to Osborne. *Sci. Educ.* 103, 1289–1293. doi: 10.1002/sce.21538

Hashweh, M. (1988). Descriptive studies of students' conceptions in science. *J. Res. Sci. Teach.* 25, 121–134. doi: 10.1002/tea.3660250204

Hewson, P. W., and Hewson, M. A. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instruct. Sci.* 13, 1–13. doi: 10.1007/BF00051837

Jonane, L. (2015). Using analogies in teaching physics: A study on Latvian teachers' views and experience. *J. Teach. Educ. Sustain.* 17, 53–73. doi: 10.1515/jtes-2015-0011

Juliyanto, E., and Siswanto, S. (2021). An analysis of thinking patterns of natural sciences teacher candidate students in understanding physics phenomena using P-Prims perspective. *J. Phys.* 1918:022043. doi: 10.1088/1742-6596/1918/2/022043

Kowalski, P., and Taylor, A. K. (2004). Ability and critical thinking as predictors of change in students' psychological misconceptions. *J. Instruct. Psychol.* 31, 297–303.

Kowalski, P., and Taylor, A. K. (2009). The effect of refuting misconceptions in the introductory psychology class. *Teach. Psychol.* 36, 153–159. doi: 10.1080/00986280902959986

Kuhn, T. (1970). *The Structure of Scientific Revolutions*, 2nd Edn. Chicago: The University of Chicago Press.

Limon, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learn. Instruct.* 11, 357–380. doi: 10.1016/S0959-4752(00)00037-2

Lucas, U., and Mladenovic, R. (2009). The identification of variation in students' understandings of disciplinary concepts: The application of the SOLO taxonomy within introductory accounting. *High. Educ.* 58, 257–283. doi: 10.1007/s10734-009-9218-9

McGuigan, N., and Weil, S. (2011). Addressing a 'preconceptual threshold': A transformation in student preconceptions of introductory accounting, ACCESS Critical Perspectives on Communication. *Cult. Policy Stud.* 30, 15–33.

Naeem Sarwar, M., Shahzad, A., Ullah, Z., Raza, S., Wasti, S., Shrahili, M., et al. (2024). Concept mapping and conceptual change texts: A constructivist approach to address the misconceptions in nanoscale science and technology. *Front. Educ.* 9:1339957. doi: 10.3389/feduc.2024.1339957

Ogborn, J., Kress, G., Martins, I., and McGillicuddy, K. (1996). *Explaining Science in the Classroom*. Buckingham: Open University Press.

Oogarah-Pratap, B., Bholoa, A., and Ramma, Y. (2020). "Stage theory of cognitive development—jean piaget," in *Science Education in Theory and Practice*, eds B. Akpan and T. J. Kennedy (Cham: Springer), 133–148. doi: 10.1007/978-3-030-43620-9_10

Osborne, J. F., Black, P., Meadows, J., and Smith, M. (1993). Young children's (7 – 11) ideas about light and their development. *Int. J. Sci. Educ.* 15, 83–93. doi: 10.1080/0950069930150107

Ozdemir, G., and Clark, D. (2007). An overview of conceptual change theories. *Eur. J. Math. Sci. Technol. Educ.* 3, 351–361. doi: 10.12973/ejmste/75414

Piaget, J. (1928). *The Child's Conception of the World*. London: Routledge.

Piaget, J. (1977). *The Development of Thought: Equilibration of Cognitive Structures*. Berkeley, CA: University of California.

Planinic, M., Krsnik, R., Pecina, P., and Susac, A. (2005). "Overview and comparison of basic teaching techniques that promote conceptual change in students," in *Proceedings of 1st European Physics Education Conference*, (Bad Honnef).

Posner, G., Strike, K., Hewson, P., and Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Sci. Educ.* 66, 211–227. doi: 10.1002/sce.3730660207

Reinking, D., Labbo, L., and McKenna, M. (2002). From assimilation to accommodation: A developmental framework for integrating digital technologies into literacy research and instruction. *J. Res. Read.* 23, 110–122. doi: 10.1111/1467-9817.00108

Sadler, P., and Sonnert, G. (2016). Understanding misconceptions: Teaching and learning in middle school physical science. *Am. Educ.* 40, 26–32.

Toulmin, S. E. (1972). *Human Understanding: The Collective use and Evolution of Concepts*. Oxford: Oxford University Press.

Verkade, H., Mulhern, T., Lodge, J., Elliott, K., Cropper, S., Rubinstein, B., et al. (2017). *Misconceptions as a Trigger for Enhancing Student Learning in Higher Education*. Melbourne: The University of Melbourne.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learn. Instruct.* 4, 45–69. doi: 10.1016/0959-4752(94)90018-3

Vosniadou, S. (2019). The development of students' understanding of science. *Front. Educ.* 4:32. doi: 10.3389/feduc.2019.00032

Zohar, A., and Aharon-Kravetsky, S. (2005). Exploring the effects of cognitive conflict and direct teaching for students of different academic levels. *J. Res. Sci. Teach.* 42, 829–855. doi: 10.1002/tea.20075

Appendix

Pre-test and Post-test questions for expense instruction using the assimilative analogy method

Pre-test (it was undertaken before the instruction of assimilative analogies)

Please fill a number in each empty blanket and reflect your understanding of your answer.

Question 1.

At the beginning of a year, A business spent $100 to buy a table which can be used for 10 years.

At the end of this year An expense of _____ is recorded.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Question 2.

At the beginning of a year, a taxi driver spent $200 to get a 5-year driving licence. An expense of _____ is recorded at the end of the year.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Question 3.

A business spent $200 to purchase inventory and then sold half inventory for $300. An expense of _____ is recorded.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Question 4.

A business paid $200 to the supplier and would not receive the goods until next year. An expense of _____ is record.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Post-test (to test the understanding of expenses after the instruction based on assimilative analogies)

Question 1.

At the beginning of a year, A business spent $150 to buy a table which can be used for 5 years. An expense of _____is recorded at the end of this year.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Question 2.

At the beginning of a year, a taxi driver spent $240 to get a 6 years driving license. An expense of _____ is recorded at the end of the year.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Question 3.

A business spent $400 to purchase inventory and then sold half inventory for $500. An expense of _____ is recorded.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Question 4.

A business paid $300 to the supplier and would not receive the goods until next year. An expense of _____ is record.

For this answer,

A. I can confirm my answer.

B. I reasonably guess the answer.

C. I know little or nothing about it (thus, no answer is provided for the question)

Self-reporting questions

1. Do you feel that this instruction has enhanced to your understanding of expenses and clarified any prior misunderstandings?
2. In your view, what are the major benefits and weakness of this instruction.