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Recomposition Based Learning for Promoting Structural Understanding
- From Reconstruction of External Representations to Recomposition of Internal Representation-

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Abstract: In educational settings, structured external representations, such as diagrams, examples, or concept maps, are often assumed to ensure learners' understanding. However, recognition of a representation does not guarantee that its underlying meaning has been internalized. Understanding involves not only the elemental meaning conveyed by individual components but also the structural meaning that emerges from their organization; the additional meaning constructed through this organization can be defined as constructed meaning ("constructed meaning = structural meaning – elemental meaning"). To foster this constructed meaning, we propose Recomposition Based Learning, a framework in which learners reconstruct a target structure from predefined components. This process externalizes, compares, and refines learners' internal representations, thereby promoting structural understanding and metacognitive reflection. By focusing on the manipulation of external representations to refine internal ones, the framework reduces cognitive load while preserving the need for interpretive reasoning. It is formalized as a four-stage cycle: (1) hypothetical recomposition, (2) difference detection, (3) conceptual clarification and completion, and (4) reflective recomposition. This paper outlines the theoretical basis of the framework.
Keywords: Recomposition Based Learning, Structural Understanding, External and Internal Representation, Kit-Build Concept Map

1. Introduction

In educational settings, learning content is often presented through structured external representations, visible and manipulable formats such as diagrams, tables, or concept maps. While these representations may appear to convey knowledge clearly and objectively, a learner's understanding depends not only on what is presented but also on how it is internally interpreted. External representations, provided by teachers, must be mentally reconstructed into internal representations, namely, the learner's own conceptual framework of meaning.

Understanding involves both the elemental meaning carried by individual components and the structural meaning arising from their organization. The difference between these, constructed meaning, is the additional meaning generated through organizing components into a coherent structure ("constructed meaning = structural meaning – elemental meaning"). A mismatch in constructed meaning often arises between what is shown and what is actually understood.

Despite this, instruction frequently proceeds under the implicit assumption that recognition of a representation implies understanding. Learners are often not required to reconstruct or articulate the underlying meaning themselves, and practical constraints such as limited class time, curriculum coverage, and standardized assessments reinforce a reliance on recognition rather than reconstruction. As a result, surface-level recognition is often mistaken for comprehension.

To address this gap between visible structure and internal comprehension, we propose Recomposition Based Learning, a structured learning framework in which learners reconstruct target structures from predefined components. This process supports learners in externalizing, comparing, and refining their internal representations, thereby fostering constructed meaning. In contrast to open-ended scratch-building, which demands high generative effort and yields highly variable outputs, recomposition reduces cognitive load while still engaging learners in interpretive reasoning. This approach narrows the scope of possible arrangements of the given components, while ensuring that learners must still engage in semantic interpretation.

This study (1) frames the refinement of internal representations through the manipulation of external ones as a core principle for promoting structural understanding, (2) proposes Recomposition Based Learning as a pedagogically grounded framework for fostering constructed meaning, (3) offers design implications for learning environments that align external representations with internal understanding. In this paper, Recomposition Based Learning is introduced as an implementation using concept maps, called the Kit-Build Concept Map (KB map for short) (Hirashima et al. 2015, Hirashima 2024).

2. Learning of Internal Representation through the Manipulation of External Representations

This section outlines the theoretical foundations of our study, focusing on the distinction and interaction between external and internal representations, and on how the manipulation of external representations can refine internal ones.

2.1 External and Internal Representations

A crucial distinction in learning theory lies between external representations—such as diagrams, tables, or concept maps—and internal representations, which refer to the learner's mental models or conceptual structures (Norman, 1993; Zhang, 1997). External representations make knowledge structures visible and manipulable, thereby supporting cognitive processes. However, comprehension ultimately depends on how learners interpret and organize the presented information internally.

Understanding consists of two components: (1) Elemental meaning: the meaning inherent in individual components of a representation. (2) Structural meaning: the meaning arising from the organization and interrelation of these components. The constructed meaning is the additional meaning that emerges from integrating elemental meanings into a coherent structure. Achieving alignment between external and internal representations means ensuring that learners not only recognize the elements but also construct the intended meaning from their relationships. Ainsworth (2006) emphasizes that such alignment is both essential and inherently difficult to achieve because learners bring different prior knowledge and interpretive frameworks. Even when an external representation appears unambiguous, the constructed meaning derived by different learners can vary widely.

Scaife and Rogers (1996) further articulate how graphical representations function within external cognition, highlighting the role of design in facilitating the transition from perception to conceptual understanding. Therefore, effective learning design should not merely present well-structured external content but also engage learners in actively manipulating and reconstructing these structures. This process externalizes internal interpretations, making them visible for comparison, reflection, and refinement. Through such interaction, learners progressively sophisticate their internal representations, strengthening both their structural understanding and metacognitive awareness.

2.2 Constructive Constructivism: A Theoretical Possibility

While constructivist learning theories emphasize the active role of learners in meaning-making, our framework highlights a specific dimension of this process: the generation of constructed meaning as the difference between elemental and structural meanings. We term this perspective Constructive Constructivism. From this view, learning is understood not merely as acquiring elemental or structural meaning, but as the iterative reconstruction of their differences. By explicitly treating these differences as objects of learning, Constructive Constructivism extends conventional constructivist perspectives, offering a more precise theoretical grounding for how external representations can be employed to refine internal ones.

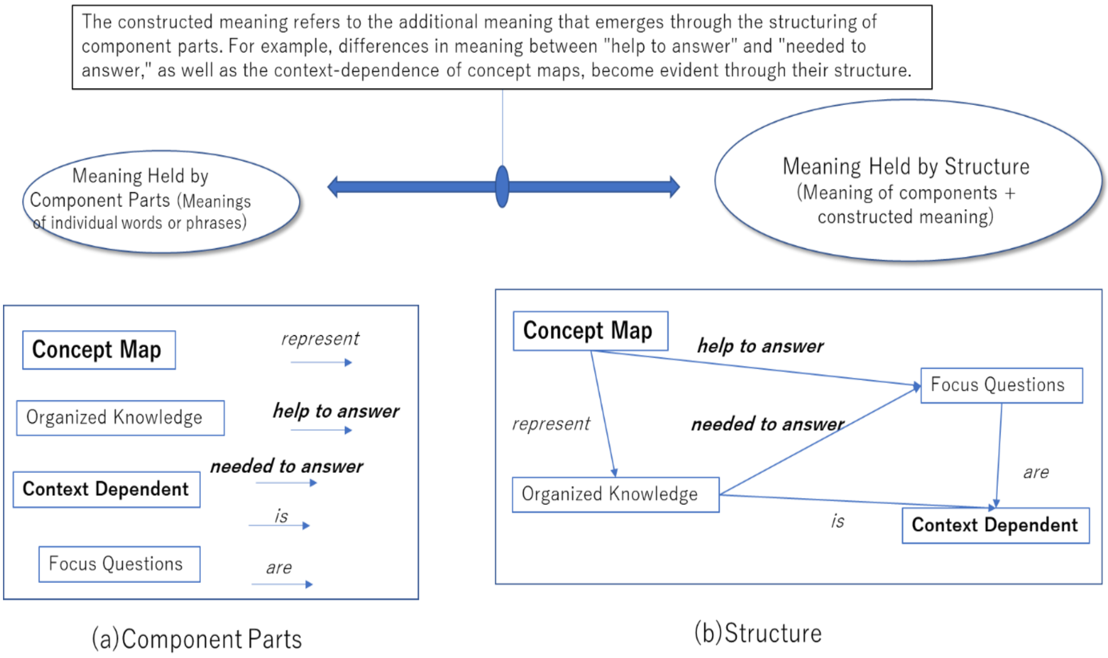

Figure 1. Relationship between External and Internal Representations in Conceptual Understanding: A Case of a Concept Map about Concept Maps

3. Illustrative Case: Recomposition of a Part of Concept of Concept Map

As defined by Novak and Cañas (2008), a concept map is a graphical tool for organizing and representing knowledge through nodes and labeled links, explicitly encoding the relationships between concepts. This characteristic makes it a suitable medium for examining both elemental and constructed meanings in our framework. Figure 1 shows the relationship between meanings held by individual components and those held by the overall structure. In panel (a), “Component Parts” represent the elemental meaning of individual words or phrases, such as Concept Map, Organized Knowledge, Context Dependent, and Focus Questions. These elements, along with linking phrases like represent, help to answer, needed to answer, is, and are, each carry meaning on their own.

However, as shown in panel (b), when these components are connected into a coherent structure, they convey structural meaning, that is, integrated meaning derived from their relationships. The difference between the structural meaning and the sum of the elemental meanings is the constructed meaning: the additional meaning that emerges only through the organization of components.

For example, in the structure, the distinction between help to answer and needed to answer becomes evident, as does the way Context Dependent relates to Focus Questions through are. These nuances are not apparent when looking at individual components in isolation but emerge through their arrangement. This example demonstrates that learning from structured representations requires learners to construct meaning beyond simply recognizing components. In Recomposition Based Learning, learners reconstruct such structures from provided components, making their internal understanding of both elemental and constructed meaning visible for reflection and refinement.

4. Recomposition Based Learning Framework

4.1 Overview

This framework is grounded in the premise that understanding emerges through a dynamic interplay between internal and external representations, and that the refinement of internal representations can be effectively supported through the manipulation of external ones.

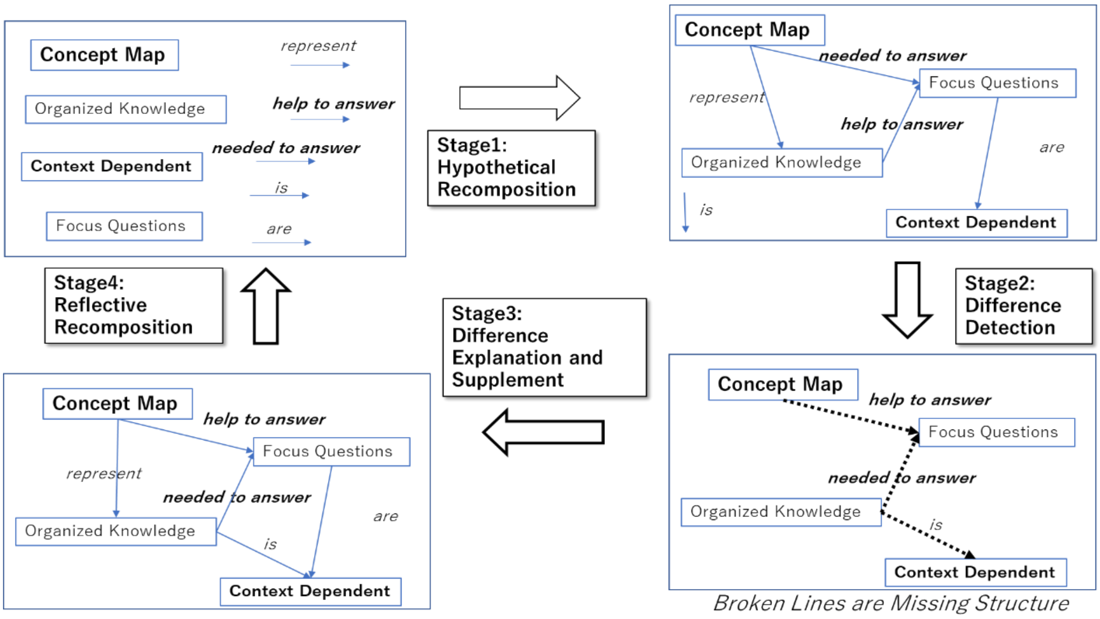

Figure 2. Four Stages of Recomposition Based Learning

In this framework, learners reconstruct structured knowledge using predefined components, thereby externalizing their internal understanding. Unlike open-ended construction tasks, which often impose high cognitive demands by requiring learners to generate components independently, recomposition enables learners to focus on interpreting and organizing meaning, rather than generating content from scratch. This design reduces cognitive load and facilitates clearer comparisons across learners, making external representations more diagnosable and sharable. These features support both metacognitive engagement and collaborative learning.

Recomposition tasks explicitly engage learners' internal representations by requiring them to assemble a coherent structure from given components. Through the processes of comparison, explanation, and revision, learners are encouraged to reflect not only on the structural configurations but also on their associated meanings. Even when a reconstruction, based merely on recall, appears structurally accurate, the act of recomposition can reveal conceptual uncertainty, prompting metacognitive awareness. This contrast between surface-level correctness and semantic ambiguity provides a powerful opportunity for engaging learners in conceptual inquiry and reflective understanding.

4.2 Four Stages of Recomposition Based Learning

4.2.1 Stage1: Hypothetical Recomposition

In the first stage, learners are provided with a set of components—such as concept nodes and relational links—and are asked to reconstruct a target structure. This reconstruction is guided by the learner's current internal representations and may result in a structure that aligns or misaligns with the expected model. The act of recomposing is inherently hypothesis-driven, as learners must interpret and infer the intended relationships. This stage makes visible the learner's initial conceptual model.

As shown in Figure 2, a set of nodes and links are provided as components (top left). In Stage 1, the learner connected four of the links, while one remains unconnected(top right). The resulting concept map (learner map) offers valuable diagnostic information about the learner's understanding.

4.2.2 Stage 2: Difference Detection

After the initial recomposition, learners compare their structure with a reference model or with peer reconstructions. This comparison enables them to identify differences not only in configuration but also in interpretive assumptions. These differences highlight discrepancies in meaning, not merely form, and draw attention to mismatches between external correctness and internal understanding.

Importantly, difference detection is not limited to identifying overt mismatches. Even when learners appear to reproduce a structure successfully based on surface-level memory, the act of comparing and justifying their composition can evoke subtle discomfort or uncertainty. Learners may become aware that, despite their structure appearing correct, they lack confidence in the underlying rationale. This realization initiates metacognitive reflection and can stimulate self-generated questioning, transforming apparent success into a springboard for deeper learning.

In the lower-right part of Figure 2, the missing structure is represented where three missing links (dashed lines) are identified. This difference map (difference learner map) is generated by overlapping the learner map and the original map.

4.2.3 Stage 3: Conceptual Clarification and Completion
In this stage, learners engage in conceptual clarification and map completion by explaining why such differences exist, by reasoning through their own decisions or interpreting the intended meaning of the target structure and supplement the differences to complete the map. This phase supports metacognitive articulation and helps learners identify the assumptions underlying their interpretations. It encourages conceptual elaboration and the refinement of internal models through clarification. The map in the lower-left part of Figure 2 shows a revised map in which the learner has explained and supplemented the differences to complete the structure.

4.2.4 Stage 4: Reflective Recomposition
Based on the insights gained, learners proceed to revise their structure. This revision is not simply a correction but a reconstruction informed by deeper understanding. It enables learners to realign their internal representations with the meaningful structure underlying the original model. This final stage represents a transformation of understanding through iterative clarification and metacognitive awareness.

4.3 Related Work on Kit-Build Concept Map and Recomposition
Previous studies have reported that the KB map system effectively supports learning in classroom settings. For instance, Pailai et al. (2017) demonstrated that using the KB map system in elementary school science classes improved learning outcomes through formative assessment. The system supports individual and collaborative learning as well as the development of higher-order thinking skills. Wunnasri et al. (2018), Sadita et al. (2020), and Pinandito et al. (2021) showed that collaborative KB map construction enhanced reading comprehension and facilitated meaningful dialogue in a second-language learning context. Compared to traditional concept mapping, learners were more inclined to ask questions about each other's maps because the system made comparison easy and structured. Nurmaya et al. (2023) and Nurmaya et al. (2025) further reported that learners using the KB map system achieved higher scores on higher-order thinking questions than those using conventional scratch-built maps. The KB map system has been successfully applied across various educational contexts, including elementary science classes, high school science instruction, university-level reading comprehension, and undergraduate information science courses. These applications demonstrate the system's flexibility and effectiveness across different subjects and learner levels. However, the fourth stage, Reflective Recomposition, has not yet been implemented as a system function and remains an important subject for future work.

5. Conclusion
In this paper, we proposed Recomposition Based Learning, a four-stage framework that externalizes and refines learners' internal representations by manipulating provided external representations. The framework is grounded in constructivist principles: learners actively build meaning by interpreting and manipulating external structures. When multiple learners work with the same set of components, compare their reconstructions, and engage in mutual

explanation, the process reflects social constructivist learning. Such sharing of structures promotes meaning negotiation and facilitates learning within the Zone of Proximal Development (ZPD). Although the final stage, Reflective Recomposition, is not yet system-guided, many learners voluntarily engaged in this phase, suggesting its perceived value and indicating promising directions for future system design. Recomposition Based Learning thus offers a practical and theoretically grounded approach to supporting both individual understanding and collaborative knowledge construction through technology-enhanced learning.

Moreover, by encouraging learners to question apparent correctness, detect inconsistencies, and reconstruct meanings beyond surface recognition, the framework also provides a foundation for higher-order educational goals such as critical and creative thinking. Recent studies support this direction; for instance, Hasani et al. (in press) demonstrated that Kit-Build concept mapping as a preparatory activity enhanced Community of Inquiry (CoI)-based asynchronous online discussions by improving learners' conceptual knowledge. Such evidence indicates that Recomposition Based Learning can serve not only as a method for refining internal representations, but also as a stepping stone toward collaborative inquiry and the cultivation of critical and creative capacities. Future work will address the implementation and empirical validation of the Reflective Recomposition stage.

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