

A CONCEPTUAL DESIGN FRAMEWORK FOR AN EDUCATIONAL COMIC INTEGRATING THREE LEVELS OF CHEMICAL REPRESENTATION FOR THE TOPIC OF MATTER

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Abstract: *This article presents a literature-informed design framework for an educational comic on matter, with emphasis on physical and chemical changes for Form Four chemistry learners. The framework aligns the proposed Three-Level Representation Visualisation Model with comic-based learning activities. Constructivism provides the overarching view of learning, while dual coding and interdependent model of the three levels of chemical representation inform the coordination of verbal explanations and visual representations. Macroscopic observations, microscopic particle models and symbolic expressions form the content structure. Analogy, modelling and concept mapping provide the selected visualisation skills activities. ADDIE organises the instructional design process within the broader research programme, which separately addresses the development of the visualisation model and the evaluation of learning outcomes. The article explains how these foundations can be translated into episode sequencing, and guiding questions connecting the three representation levels. It also presents illustrative specifications for physical and chemical changes. The contribution is a theoretically grounded route from the visualisation model to the comic design.*

Keywords: *educational comic; matter; chemical representation; visualisation skills; constructivism; dual coding; interdependent model of the three levels of chemical representation; ADDIE*

Introduction

Understanding changes in matter calls for more than recognising what can be seen. Learners also need to explain those observations in terms of particles and to interpret the chemical notation used to represent the same process. These explanatory tasks operate at different representational levels, and moving between them may be challenging (Johnstone, 1991, 2000). For this reason, the proposed comic is designed to draw attention to the connections between representations rather than present words and pictures as unrelated elements.

The development concerns a comic based on a Three-Level Representation Visualisation Model for the topic of matter. Its objectives include developing the visualisation model and then developing a comic guided by that model. This article focuses on that relationship. The model specifies the conceptual connections and visualisation skills activities to support; the comic provides the narrative and visual medium through which learners can work with them. Measuring changes in understanding and visualisation is a further research objective and is outside the present paper's scope.

The aim is to articulate an instructional design framework that connects the theoretical foundations, the three representation levels and the selected visualisation skills activities with comic development. Three design questions guide the discussion: how should an episode link the representation levels; how should analogy, modelling and concept mapping support those links; and what should formative review examine before classroom use? The resulting framework is presented as a design contribution, rather than as evidence of product effectiveness.

Literature Review

Three Levels of Chemical Representation

In this framework, the macroscopic level refers to phenomena that learners can observe, whereas the microscopic level provides explanatory models of particles and their interactions. Chemical symbols, formulae and equations constitute the symbolic level. The distinction is functional: although particle models are drawn using graphic marks, they serve here as microscopic explanations rather than as symbolic equations.

Treagust, Chittleborough, and Mamiala (2003) examined the role of microscopic and symbolic representations in chemical explanations. Their work supports attention to the explanatory links among levels. Gkitzia, Salta, and Tzougraki (2011) also provide criteria for examining chemical representations in educational materials. For the present framework, each visual should identify its representational level, use clear labels and connect explicitly with the explanation it supports. Displaying three representations together does not by itself establish that learners understand their relationship.

Constructivism and the Coordination of Words and Pictures

Constructivism underpins the proposal's account of learning. Students interpret new explanations through existing ideas and may need to revise those ideas through guided activity and discussion. Driver, Asoko, Leach, Mortimer, and Scott (1994) describe science learning as involving individual and social processes of knowledge construction. Accordingly, the comic should invite prediction, explanation and reconsideration. Dialogue can make contrasting explanations visible, while teacher questioning can help learners evaluate them scientifically.

Paivio's (1986) dual coding theory provides a rationale for coordinating verbal and nonverbal representations. In a chemistry comic, verbal explanation can clarify the meaning of a visual model, while a visual can make relationships described in words easier to inspect. Mayer (2009) further informs the placement and selection of words and pictures. The design implication is to place relevant explanations near the representation they explain and remove decorative content that distracts from the chemistry. These theories support design choices.

Selected Visualisation Skills Activities

Visualisation involves interpreting representations and reasoning about what they mean, rather than simply recognising an image. Gilbert (2005) discusses visualisation as a metacognitive skill in science education. The framework therefore asks students to explain how a representation accounts for a phenomenon and to recognise its limitations. Analogy, modelling and concept mapping are retained as the three selected visualisation skills activities. Drawing and symbolisation are not treated as additional visualisation skills in this article; symbolic representation remains one of the three chemical representation levels.

Analogy provides an accessible starting point for an unfamiliar idea. Its use requires an explicit correspondence between the familiar situation and the chemical concept, followed by an explanation of where the comparison fails. Mammino (2024) highlights the design challenge of gaining the benefits of analogy while limiting misinterpretation. Modelling asks students to interpret or revise an explanatory particle model and justify its features. Concept mapping asks them to connect concepts using meaningful linking phrases. Machado and Carvalho (2020) discuss benefits and challenges of concept mapping in higher education; their review informs the activity rationale without establishing effects for Form Four learners.

Educational Comics as an Instructional Medium

A comic combines narrative sequence, dialogue and visual representation. These features can provide a setting in which a character observes a phenomenon, proposes an explanation and revises it with guidance. Studies of science comics have examined different purposes and audiences: Spiegel et al. (2013) investigated teenagers' engagement, Lin, Lin, Lee, and Yore (2015) examined public learning about nanotechnology, and Affeldt, Meinhart, and Eilks (2018) considered comics as experimental instructions in a non-formal chemistry context. Together, these studies support considering comics as an educational medium while also showing why findings from one context should not be assumed to apply to another.

A comic is useful for this design purpose only when its narrative advances chemical reasoning. Dialogue can introduce an initial explanation, visual panels can make its assumptions visible, and a subsequent question can invite revision. Labels and scale conventions remain important: attractive particle illustrations without sufficient explanation could encourage incorrect interpretations. The proposed resource therefore pairs the storyline with tasks that ask learners to account for the represented phenomena.

Methodology

Scope and Relationship to the Research Programme

This article sets out a conceptual framework informed by the research proposal and the cited scholarship. It does not report a completed needs analysis, participant-based study, expert validation or classroom trial. The proposal establishes the intended topic, theoretical perspective and instructional objectives; the published literature informs the principles used to

organise the design. Consequently, examples presented below are design illustrations rather than observations collected from students.

The wider programme separates instrument work, investigation of students' understanding and visualisation, development of the model and comic, and evaluation of learning outcomes. The proposal includes written responses and think-aloud interviews as ways to investigate student reasoning. Bowen (1994) discusses the use of think-aloud methods in chemistry education. These procedures provide methodological context, but this paper does not claim that interviews, instrument validation or model validation have been completed. Any later empirical account should state the actual procedures and participants.

Conceptual synthesis procedure. The framework was developed through a theory-informed mapping exercise rather than a systematic review or empirical validation. First, the article identifies design principles from the cited literature on chemical representations, constructivism, dual coding, multimedia learning, and educational comics. Second, each principle is mapped to one of three design components: representational content (macroscopic, microscopic, and symbolic), learner activity (analogy, modelling, and concept mapping), or instructional sequencing (ADDIE). Third, illustrative guiding questions for physical and chemical changes are derived to show how these components could be coordinated in a comic episode. These examples are design propositions, not observed outcomes or evidence of effectiveness.

The distinction between the research phases and ADDIE is essential. The research phases address the overall sequence of inquiry. ADDIE organises the instructional development of the comic within that programme (Branch, 2009). Model development specifies what the comic should support; instructional development translates those specifications into a usable resource. Formative product evaluation and the subsequent assessment of learning outcomes answer different questions.

ADDIE as the Development Framework

Analysis identifies the instructional scope from the curriculum content, theoretical framework and literature. For this article, the design requirement is to connect observable changes, particle explanations and symbolic accounts of matter. Design translates this requirement into learning objectives, episode sequences and guided learning questions. Development translates the specifications into storyboards, dialogue, representations and learning tasks.

Implementation concerns how the comic will be used during instruction, including the teacher's guidance and students' opportunities to discuss and explain representations. Evaluation includes formative checking of scientific accuracy and instructional clarity, followed by revision where needed. Evaluation of learning outcomes belongs to the separate intervention component. The proposal's intended duration, sample sizes and expert composition should only be reported as completed procedures once the actual records are confirmed.

THEORETICAL FOUNDATIONS
Constructivism · Dual coding · Three-level chemical representation model
REPRESENTATIONAL CONTENT
Macroscopic observation ↔ Microscopic particle model ↔ Symbolic expression
VISUALISATION ACTIVITIES
Analogy · Modelling · Concept mapping
ADDIE-GUIDED COMIC DESIGN
Analysis → Design → Development → Implementation → Evaluation

Figure 1. Conceptual mapping from theoretical foundations to comic design specifications

Note. The arrows express intended instructional connections, not empirically verified effects. ADDIE is an instructional development framework within the wider research programme.

Design Framework and Discussion

From the Visualisation Model to the Comic

The proposed model connects three chemical representation levels with the selected visualisation activities. The levels organise the chemistry content; the activities organise how students reason about it. The framework is therefore expressed as a set of relationships, rather than a simple list of images to include. A learning objective should identify both the relevant chemistry concept and the connection that students are expected to explain.

For example, an objective for melting is to explain an observable change of state using particle arrangement and movement, and to interpret a suitable state notation. An objective for a chemical change is to relate observable evidence to a model in which atoms are rearranged into products and to an appropriate equation. These are illustrative specifications for the comic, not descriptions of verified panels or student responses. They show how the model can guide decisions about content and activity.

Episode Sequencing and Cross-Level Guiding Questions

An episode can begin with a familiar event and a prediction question. The following panels introduce a particle model and ask students to compare it with their initial explanation. The symbolic account then expresses the same event using suitable notation. A concluding guiding question requires learners to connect all three accounts. The sequence should also permit movement back from an equation or particle model to the observable event, because understanding should not depend on a single direction of presentation.

In the melting example, a macroscopic scene shows ice becoming liquid water. The microscopic model should maintain the identity of water molecules while showing differences in their arrangement and motion. The symbolic expression $\text{H}_2\text{O}(\text{s}) \rightarrow \text{H}_2\text{O}(\text{l})$ then communicates a change of state without implying a new substance. A question such as “What changes, and what remains the same?” directs attention to the relationship between the visible event and the molecular account.

For a chemical change, the design should distinguish reaction evidence from the explanation of what happens to particles. A possible symbolic example is $2\text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{MgO}(\text{s})$. A corresponding particle model must conserve the number of each type of atom while representing the reactants and product consistently. Magnesium oxide should not be drawn as isolated molecules if the lesson is representing its ionic structure. Such checks prevent the

narrative from creating misconceptions through visually convenient but chemically inappropriate models.

Integrating the Three Activities

An analogy-based guiding question should ask learners to identify the useful correspondence and its limit. For instance, a seating arrangement may help introduce differences in spatial organisation, but it cannot adequately represent the continuous motion or interactions of particles. The comic dialogue should explicitly acknowledge these limits. A model-based guiding question should then ask learners to justify a particle arrangement or explain why an alternative model is unsuitable.

A concept-mapping task can consolidate links among matter, physical change, chemical change, particles and conservation. Linking phrases are necessary because a collection of connected labels may hide an unclear explanation. The task should also ask students to identify which links require macroscopic evidence, microscopic reasoning or symbolic expression. In this way, concept mapping connects the content across the episode rather than serving as a decorative end-of-lesson activity.

Contribution and Limitations

The main contribution is an explicit design logic: chemistry content is organised across macroscopic, microscopic and symbolic representations, while analogy, modelling and concept mapping define how learners are invited to reason about those representations. This distinction can guide the drafting and review of comic episodes. It should not, however, be interpreted as evidence that the framework has been validated or that the comic improves learning outcomes. The present account is limited to the design rationale. It does not establish that the model is empirically validated, that the comic has passed expert review or that classroom learning has improved. The supplied proposal documents intentions, so it cannot replace actual production records, reviewed comic panels or evaluation data. A completed development-study report will require those materials. The separate outcomes article should use the verified intervention design and data and should avoid attributing changes solely to the comic beyond what that design supports.

Conclusion

An educational comic on matter can be structured around explicit connections among macroscopic observations, microscopic models and symbolic expressions. The proposed Three-Level Representation Visualisation Model supplies the conceptual direction, while constructivism, dual coding and multimedia learning inform the learning activities and presentation. ADDIE provides an organising process for comic development within the wider research programme. Analogy, modelling and concept mapping are the selected activities for helping learners explain these connections. The contribution of this article is the aligned design framework; product validation and learning effectiveness remain questions for verified empirical reporting.

Declarations

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References

- Affeldt, F., Meinhart, D., & Eilks, I. (2018). The use of comics in experimental instructions in a non-formal chemistry learning context. *International Journal of Education in Mathematics, Science and Technology*, 6(1), 93–104. <https://doi.org/10.18404/ijemst.380620>
- Bowen, C. W. (1994). Think-aloud methods in chemistry education: Understanding student thinking. *Journal of Chemical Education*, 71(3), 184–190. <https://doi.org/10.1021/ed071p184>
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. New York, NY: Springer. <https://doi.org/10.1007/978-0-387-09506-6>
- Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5–12. <https://doi.org/10.3102/0013189X023007005>
- Gilbert, J. K. (2005). Visualization: A metacognitive skill in science and science education. In J. K. Gilbert (Ed.), *Visualization in science education* (pp. 9–27). Dordrecht, Netherlands: Springer. https://doi.org/10.1007/1-4020-3613-2_2
- Gkitzia, V., Salta, K., & Tzougraki, C. (2011). Development and application of suitable criteria for the evaluation of chemical representations in school textbooks. *Chemistry Education Research and Practice*, 12(1), 5–14. <https://doi.org/10.1039/C1RP90003J>
- Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, 7(2), 75–83. <https://doi.org/10.1111/j.1365-2729.1991.tb00230.x>
- Johnstone, A. H. (2000). Teaching of chemistry—Logical or psychological? *Chemistry Education Research and Practice*, 1(1), 9–15. <https://doi.org/10.1039/A9RP90001B>
- Lin, S.-F., Lin, H.-S., Lee, L., & Yore, L. D. (2015). Are science comics a good medium for science communication? The case for public learning of nanotechnology. *International Journal of Science Education, Part B*, 5(3), 276–294. <https://doi.org/10.1080/21548455.2014.941040>
- Machado, C. T., & Carvalho, A. A. (2020). Concept mapping: Benefits and challenges in higher education. *The Journal of Continuing Higher Education*, 68(1), 38–53. <https://doi.org/10.1080/07377363.2020.1712579>
- Mammino, L. (2024). Maximizing advantages and minimizing misinterpretation risks when using analogies in the presentation of chemistry concepts: A design challenge. *Physical Sciences Reviews*, 9(6), 2195–2220. <https://doi.org/10.1515/psr-2022-0318>
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York, NY: Cambridge University Press. <https://doi.org/10.1017/CBO9780511811678>
- Paivio, A. (1986). *Mental representations: A dual coding approach*. New York, NY: Oxford University Press.
- Spiegel, A. N., McQuillan, J., Halpin, P., Matuk, C., & Diamond, J. (2013). Engaging teenagers with science through comics. *Research in Science Education*, 43, 2309–2326. <https://doi.org/10.1007/s11165-013-9358-x>
- Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, 25(11), 1353–1368. <https://doi.org/10.1080/0950069032000070306>