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Bibliometric-Based Needs Analysis of Comic-Based Multiple Representation Learning Media on Thermochemistry

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Abstract

Thermochemistry presents considerable learning challenges because students must simultaneously interpret energy changes at the particle level and relate them to observable phenomena and symbolic notations. Such cognitive complexity often leads to low motivation and difficulties constructing coherent conceptual understanding. In alignment with the Merdeka Curriculum, learning media in chemistry should therefore emphasize visual clarity, contextual learning experiences, and active student engagement. However, instructional comics that are widely used in classrooms typically highlight narratives and illustrations without fully accommodating the integration of macroscopic, submicroscopic, and symbolic representations. This study aims to identify research needs for the development of comic-based multiple representation learning media in Thermochemistry by examining publication trends in recent chemistry education research. A bibliometric approach was applied to analyze 295 scientific articles using keyword co-occurrence mapping in VOSviewer. The results show that Thermochemistry, multiple representations, learning media, and educational comics are recurring topics of interest, yet they tend to appear in separate thematic clusters with minimal conceptual linkage. These patterns indicate that research integrating the four domains remains limited. Thus, the findings provide strong justification for the future development of comic-based learning media that explicitly support representational transitions to enhance students' conceptual understanding of Thermochemistry.

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INTRODUCTION

Chemistry is frequently perceived as demanding and less engaging because many of its concepts involve symbolic formalism and microscopic processes that students cannot directly observe (Rosa, 2015; Novratilova et al., 2015). As a result, learners often struggle to build interest and develop a thorough conceptual understanding, which may lead to fragmented knowledge and misconceptions (Marsita et al., 2010; Ristiyani & Bahriah, 2016). These challenges show that chemistry learning requires instructional support that can help students form meaningful mental connections.

A key component of successful chemistry learning lies in students' ability to coordinate multiple forms of representation. Gabel (1999) and Johnstone (2000) describe chemical ideas as residing at three complementary levels: macroscopic phenomena, particle-level explanations, and symbolic descriptions. When students are unable to relate these levels, their reasoning remains incomplete and prone to conceptual errors. Gilbert and Treagust (2009) highlight that learning designed with multiple representations can guide students to construct scientifically valid interpretations across these levels.

Difficulties in thermochemistry exemplify this representational gap. Students need to interpret observable temperature changes while understanding energy transfer at the molecular level and applying symbolic equations for enthalpy. Prior studies have consistently reported that linking these representations poses a major challenge (Febriyanti et al., 2019; Husna, 2019; Suyatman & Taher, 2020; Afriani et al., 2022). Therefore, learning supports that reinforce representational connections are essential to reduce misconceptions and foster conceptual coherence in this topic.

Learning media can serve as an intermediary to translate abstract chemical phenomena into accessible visual and contextual forms. Media such as educational comics provide narrative and imagery that can sustain attention, encourage curiosity, and facilitate comprehension of complex ideas (Arafat Lubis, 2018; Emilia et al., 2022; Abrori et al., 2024). Nevertheless, several analyses of existing chemistry comics report that many are limited to illustrative storytelling, without explicitly incorporating the three representational levels needed for deeper conceptual understanding (Oktapianti, 2021). Consequently, the potential of comics to support scientific reasoning has not been fully realized in classroom practice.

To identify research gaps regarding representational support in chemistry media, bibliometric analysis was employed in this study. Bibliometrics enables systematic evaluation of scholarly trends by examining keyword networks, authorship patterns, and thematic structures across publications (McBurney & Novak, 2002; Szomszor et al., 2021). Using VOSviewer, this study analyzed 295 articles related to thermochemistry, multiple representations, learning media, and educational comics. The visualization results show that these four themes appear as distinct clusters, indicating limited integration in existing research. Thus, there is strong empirical support for the development of learning media that unify these concepts.

Based on these theoretical insights and bibliometric evidence, this study aims to analyze the necessity of developing comic-based multiple representation learning media on thermochemistry for senior high school students to enhance representational fluency and support conceptual understanding in accordance with the Merdeka Curriculum.

METHODS

Research Type

This research used secondary data obtained from scientific publications related to Thermochemistry, multiple representations, learning media, and educational comics. In total, 295 articles were collected from accessible online databases, including Google Scholar, Lens.org, Scopus, and other reputable journals. Only documents containing complete metadata (title, author(s), year, abstract, and keywords) were included. Because all data analyzed were publicly available and did not involve human participation or personal information, no ethical clearance was required. The metadata were processed solely for academic purposes.

Searching Strategy

A systematic literature search was conducted using combinations of keywords such as thermochemistry, multiple representation(s), learning media, comic, and chemistry education with Boolean operators to refine results. Publications were selected if they: focused on chemistry education or instructional media, were written in Indonesian or English, provided complete bibliographic information, and were available in an exportable format. Non-relevant and duplicate items were screened out before the remaining articles were compiled into a unified CSV dataset.

Data Extraction and Preparation

Exported data (RIS/CSV format) were standardized into five essential metadata fields: Title, Authors, Year, Abstract, and Author Keywords. During preprocessing, misspellings were corrected, author names were normalized, and missing entries were checked manually when possible. A thesaurus file was created to merge synonymous terms and remove irrelevant or overly generic keywords to ensure accurate visualization results in the mapping stage.

Bibliometric Analysis

Keyword co-occurrence mapping was carried out using VOSviewer, selected for its capability to display bibliometric networks clearly and interactively. Visualization parameters were optimized by increasing node attraction and reducing repulsion to produce clearer keyword clusters. Other settings remained in their default

configurations within VOSviewer to ensure stable and readable mapping results. The software generated network and density maps to illustrate thematic relationships and research hotspots within the dataset.

Data Interpretation

Interpretation was based on node size to indicate keyword frequency, link strength to show co-occurrence relationships, and cluster colors to categorize thematic groups. The spatial distribution of the keywords was examined with particular attention to the positioning of Thermochemistry, multiple representations, learning media, and comics. These patterns were used to identify research directions and the absence of integrated studies that combine representational theory with comic-based learning media.

FINDINGS AND DISCUSSION

Findings

A total of 295 publications were obtained and analyzed using a keyword co-occurrence technique in VOSviewer. The initial dataset contained 278 keywords, which were all included in the analysis because the minimum occurrence threshold was set to 1, allowing for a comprehensive mapping of scientific concepts related to thermochemistry, multiple representations, learning media, and comics. The analysis generated 28 clusters, indicating a broad diversity of topics that have been explored within the domain of chemistry education.

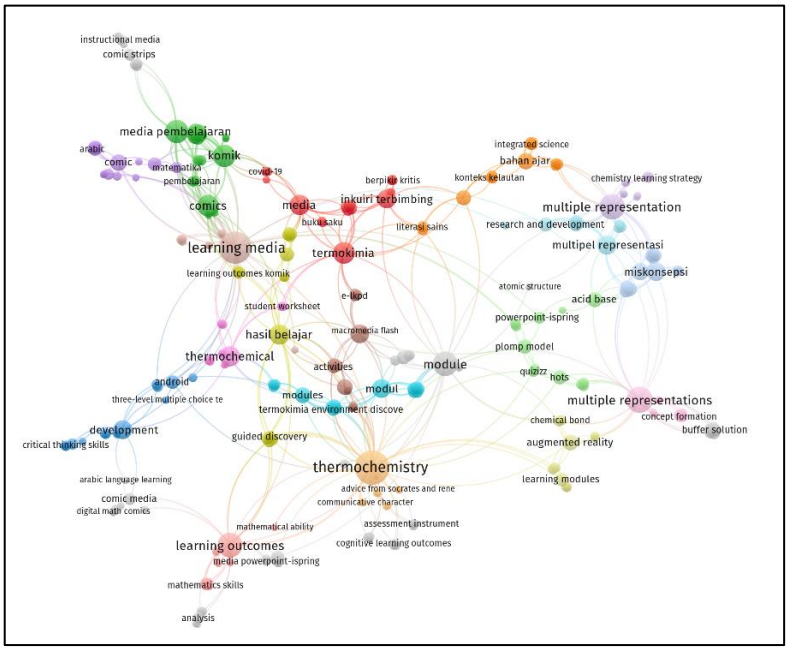

Figure 1. Network Visualization

The network visualization revealed several dominant thematic clusters characterized by highly occurring keywords and strong linkages among them. The most prominent nodes included thermochemistry, multiple representations, learning media, module, comics, and learning outcomes, showing that these topics have attracted considerable research attention. However, these keywords were distributed across different clusters with limited interconnection. For example, “thermochemistry” was positioned within a cluster focusing on learning outcomes and assessment, while “comics” was grouped within a cluster related to general learning media and student motivation. Meanwhile, “multiple representations” and “misconceptions” appeared in a separate cluster focused on conceptual understanding. The separation of these clusters suggests that research integrating thermochemistry, multiple representations, and comic-based learning media has not yet been widely conducted.

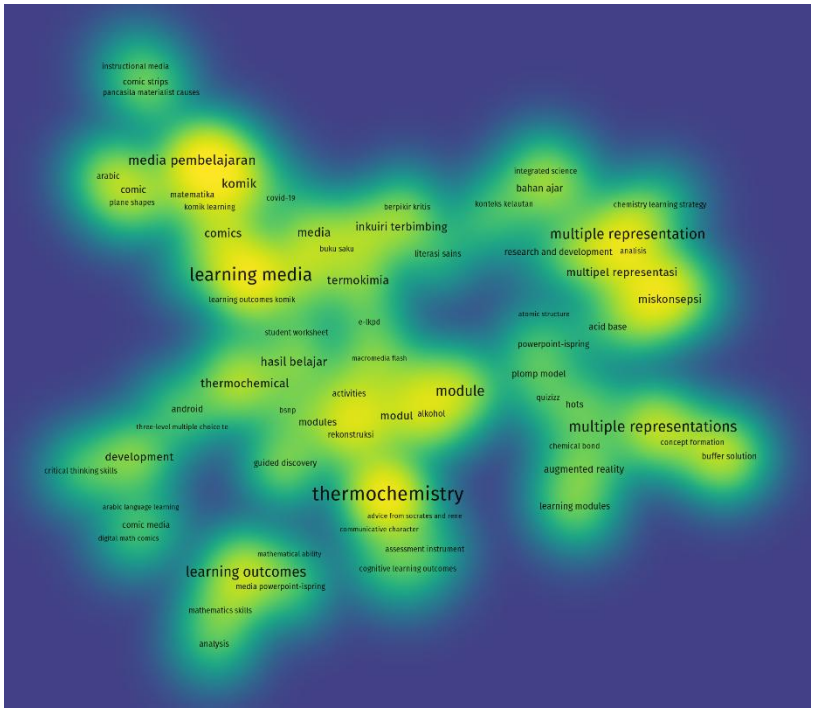

Figure 2. Density Visualization

The density visualization further supports this finding by showing several hotspot areas concentrated around high-frequency keywords such as thermochemistry, learning media, multiple representations, and module. These hotspots indicate strong research activity, yet the brightest regions do not overlap between the topics of comics and thermochemistry. The distribution pattern shows that although each concept appears as a significant focus in chemistry education research, they have not converged as a single integrated theme within published studies.

Discussion

The bibliometric mapping reveals that the major topics found in the dataset, Thermochemistry, multiple representations, learning media, and comics, remain separated into different clusters and rarely intersect. This suggests that although these themes are recognized in chemistry education research, they have not been collaboratively explored to address students' conceptual difficulties (Gabel, 1999; Johnstone, 2000; Gilbert & Treagust, 2009). A fragmented thematic structure in published findings indicates that learners may still struggle to connect chemical concepts across representational levels, as noted in several previous studies (Marsita et al., 2010; Ristiyani & Bahriah, 2016; Afriani et al., 2022).

The gap between Thermochemistry and multiple representations in the mapping shows that instructional strategies targeting representational integration are still limited in that topic area. Misunderstandings surrounding energy change and particle-level mechanisms have been frequently reported (Febriyanti et al., 2019; Husna, 2019; Suyatman & Taher, 2020), reinforcing the importance of learning materials that actively guide learners in bridging symbolic, macroscopic, and microscopic information. Theoretical perspectives emphasize that connecting these representational modes is essential for students to gradually form accurate conceptual meaning (Gilbert & Treagust, 2009).

The results also demonstrate that research on learning media and educational comics forms a strong cluster, indicating growing attention to the use of visual narratives in chemistry learning (Arafat Lubis, 2018; Emilia et al., 2022; Abrori et al., 2024). However, most existing comics focus on narrative engagement rather than incorporating representational principles systematically (Oktapianti, 2021). This finding points to a missed opportunity, considering that comics have potential to help students visualize intangible processes and maintain learning motivation when designed with scientifically valid content.

Another cluster focuses on learning outcomes, modules, and digital-based resources, suggesting that efforts in instructional development still prioritize conventional or technology-oriented materials. Although these media contribute to accessibility and independence, they may not adequately address the cognitive challenges that stem

from representational complexity. Meanwhile, comics can provide a storyline that gradually introduces conceptual links, if developed with explicit representational transitions (Gilbert & Treagust, 2009).

Taken together, the bibliometric results and supporting theories imply that the integration of multiple representations within comic-based learning media remains an open opportunity for innovation. Addressing this research gap could generate a more coherent instructional experience in Thermochemistry, improve students' conceptual connections, and support more engaging and meaningful learning in line with the expectations of the Merdeka Curriculum.

CONCLUSION

The bibliometric analysis of 295 publications revealed that thermochemistry, multiple representations, learning media, and comics are important research topics in chemistry education but are still explored separately with limited integration. The mapping results showed that although each concept appears in productive research clusters, there is no existing study that combines the strengths of comic-based learning media with representational scaffolding to support thermochemistry learning. Therefore, this study confirms the need for developing comic-based multiple representation learning media to facilitate students' conceptual integration across macroscopic, submicroscopic, and symbolic levels. Future research should focus on designing scientifically accurate visual narratives and representational transitions within comics to enhance students' motivation, reduce misconceptions, and improve learning outcomes in thermochemistry at the senior high school level.

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