



Understanding Students' Cognitive Processes: A Qualitative Study of the Influence of Culture-Based Comics on Analytical Skills in Thermodynamics

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Article Info	Abstract
Article History Received: January 4, 2025 Accepted: July 18, 2025 Published: July 31, 2025 Keywords cultural-based learning; cognitive processes; analytical thinking; educational comics; thermodynamics; physics education; narrative learning; conceptual representation	<i>This study aims to explore how students' cognitive processes are formed and developed through their engagement with thermodynamics learning using culturally-based comics. Employing a qualitative case study design, the research involved twelve physics education students who had completed thermodynamics coursework. The learning medium used was the Longbumbung Series, an educational comic that integrates narrative and visual representations of local cultural life with thermal physics concepts. Data were collected through participatory observation, in-depth interviews, and students' written reflections, and analyzed thematically. The findings indicate that incorporating local culture into comics not only enhances students' affective engagement but also stimulates higher-order cognitive processes such as conceptual interpretation, scientific inference, and analytical articulation. Culture serves as a representational structure that bridges abstract concepts into contextual and reflective understanding. These findings highlight the importance of strategically integrating local cultural elements into science media and pedagogy design to foster deeper intellectual engagement and transformative learning experiences.</i>
Informasi Artikel	Abstrak
Kata kunci pembelajaran berbasis budaya; proses kognitif; berpikir analitis; komik edukatif; termodinamika; pendidikan fisika; narasi visual; representasi konseptual Corresponding Author Sony Yuniur Erlangga Universitas Sarjanawiyata Tamansiswa, Indonesia *E-mail: sony.erlangga@gmail.com	Penelitian ini bertujuan mengeksplorasi pembentukan proses kognitif mahasiswa melalui pembelajaran termodinamika menggunakan komik berbasis budaya lokal. Studi kasus kualitatif ini melibatkan dua belas mahasiswa pendidikan fisika yang telah mempelajari materi termodinamika. Media yang digunakan adalah Longbumbung Series, komik edukatif yang merepresentasikan prinsip fisika termal dalam konteks budaya lokal. Data dikumpulkan melalui observasi, wawancara mendalam, dan refleksi tertulis, lalu dianalisis secara tematik. Hasil menunjukkan bahwa integrasi budaya lokal dalam komik meningkatkan keterlibatan afektif mahasiswa serta mendorong proses kognitif tingkat tinggi, seperti interpretasi konseptual, inferensi ilmiah, dan artikulasi analitis. Budaya berperan sebagai struktur representasional yang menjembatani konsep abstrak menjadi pemahaman yang kontekstual dan reflektif. Temuan ini menegaskan pentingnya integrasi budaya lokal dalam desain media dan pedagogi sains untuk menciptakan pengalaman belajar yang transformatif dan bermakna.
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INTRODUCTION

Understanding physics concepts, particularly thermodynamics, requires students to have strong analytical skills to connect macroscopic phenomena with microscopic and mathematical principles. However, various studies indicate that students often struggle to develop a deep conceptual understanding of this topic, particularly in developing analytical skills to explain thermal processes and energy transformations (Ananda et al., 2021; Harahap & Rohaeti, 2021; Maspaiteella et al., 2023; Wahyudyawati & Amin, 2021). These difficulties are often influenced by the lack of contextual presentation of the material and low cognitive engagement of students in the learning process. In the context of science education, presenting material using a meaningful approach that is relevant to students' lives has been proven to increase cognitive engagement and conceptual understanding. One potential approach is the use of comics based on local culture as a learning medium (Ali, Suranto, Indrowati, Zaini, et al., 2025; Rahayu & Paristiowati, 2021). Comics as a visual-verbal medium have the ability to convey abstract concepts narratively and contextually, while the local cultural content embedded in them can increase students' relevance and emotional closeness to the material (Erlangga, 2022; Erlangga et al., 2023; Susanti et al., 2022). The integration of culture in learning media not only strengthens students' identity, but also serves as a conceptual bridge that enriches the cognitive process.

However, to date, studies that specifically examine how students' cognitive processes are formed and developed through exposure to culture-based comic media in the context of physics learning, particularly thermodynamics, are still very rare. The existing literature tends to focus on quantitative evaluation of learning outcomes, such as test score improvements or comparisons between control and experimental groups (Liu et al., 2024; Wati et al., 2024). Meanwhile, the internal dynamics of students' thinking processes—how they construct mental representations, connect visual and narrative symbols with scientific concepts, and build analytical arguments within a cultural framework—remain largely overlooked. These deep aspects are actually at the heart of true learning transformation. The lack of focus on this cognitive layer leaves a gap in our understanding of how media-based and culturally contextual learning strategies actually work in shaping students' scientific thinking structures. Yet, in modern science education that emphasises higher-order thinking, understanding the flow and mechanisms of students' thinking is key to designing effective pedagogical interventions (Ali, Suranto, Indrowati, & Suhirman, 2025). Without accurate mapping of cognitive processes, any learning innovation risks becoming merely an aesthetic visual surface, without touching the depths of the structure of understanding (Chakravarty & Dua, 2023).

Therefore, it is important to conduct qualitative exploration that can reveal the processual dimensions of students' analytical thinking, rather than merely assessing learning outcomes. By positioning cultural experience as both a medium and a context, this study does not merely aim to answer whether comic media is effective, but goes further: how and why students construct scientific meaning through cultural narratives, and to what extent this process enriches their analytical abilities in dealing with abstract concepts such as those found in thermodynamics. Such an approach not only offers conceptual contributions to physics education but also opens up space for more reflective, inclusive, and reality-based pedagogical design.

METHOD

This study uses a qualitative approach with an interpretive case study design to explore in depth how students' cognitive processes are formed when they use cultural-based comic learning media to understand basic thermodynamics concepts. This study aims not only to examine conceptual understanding but also to explore how cultural experiences and local

contexts mediated through visual and narrative media shape students' analytical thinking processes. The research was conducted in the Physics Education Study Programme at a state university in Indonesia, involving twelve fourth-semester students as the main participants. These students had previously taken the Basic Physics II course, providing them with an initial exposure to thermodynamics concepts. Participants were selected purposively, considering their diverse cultural backgrounds, adequate verbal skills, and openness to innovative learning methods (Chhabra & Gawande, 2025; Martín-García et al., 2024).

The primary medium used in this study is an educational comic titled "Longbumbung Series" as shown in Figure 1, an original comic developed specifically to combine the principles of thermal physics with the narrative of traditional community life. The story in this comic book highlights the daily lives of fictional characters living in Longbumbung village, an imaginary region that represents the values of Indonesian local wisdom. In one episode, the comic book illustrates how families in the village utilise heat energy from firewood for various household needs, such as cooking, heating water, and smoking fish. Every scene in the story explicitly or implicitly incorporates thermodynamic concepts such as conduction, convection, radiation, entropy, energy conversion, and heat efficiency. The integration of cultural narrative and scientific concepts is intended to build a meaningful connection that stimulates higher-order thinking skills, particularly analytical abilities.

The learning process took place over two class sessions, each lasting 90 minutes. In the first session, students read and discussed the contents of the comic in groups. They were asked to identify parts of the story related to physics concepts and explain how the illustrations and narrative supported their understanding. The second session focuses on reflective activities, where students are asked to write down their understanding individually and reflect on the thinking process they experienced while reading the comic. In both sessions, the researcher acts as a facilitator and observer, noting the interactions and expressions of the students throughout the process (Bukifan & Yuliati, 2021; So et al., 2021). Data collection was conducted through three main methods, namely participatory observation, in-depth interviews, and written reflection analysis. Observation was conducted to record learning phenomena that emerged naturally, such as spontaneous discussions, interpretation of illustrations, or conceptual questions raised by students. Interviews were conducted individually using a semi-structured approach to explore how students related cultural elements in comics to the physics concepts they were studying. Additionally, students' written reflections were analysed as primary data sources to understand their internal representations of the thinking process, particularly in identifying cause-and-effect relationships, making inferences, and evaluating context-based information.



Figure 1. Comic strip from the Longbumbung series

All data were analysed using a thematic approach. The analysis was conducted in stages through repeated reading of interview transcripts and reflection notes, identification of patterns that indicate analytical thinking, and formulation of relevant conceptual themes. The themes generated were not constructed a priori, but emerged from direct interaction between the researcher and the data. This analysis was reflective and iterative, with the researcher triangulating between sources (observations, interviews, and written documents) to strengthen the validity of the interpretation (Belia et al., 2023; Pill, 2016; Stalmach et al., 2024). Although direct quotations from students were used as the basis for analysis, they were presented narratively in paragraphs, without including transcripts or visual images. The main emphasis of the analysis results is how the narrative and visuals in the "Longbumbung Series" comic trigger deep cognitive construction and support students in developing scientific thinking based on cultural context. To ensure data validity, the researcher conducted member checking by asking students to review their interpretations of their statements. In addition, analysis notes were kept systematically to ensure the traceability of the interpretative process. The entire process was based on the principles of interpretative openness and reflective awareness on the part of the researcher to minimise personal bias and maintain the credibility of the findings.

RESULTS AND DISCUSSION

The results of this study indicate that the use of the Longbumbung Series comics in thermodynamics learning has a significant effect on how students build and develop their analytical skills. This process does not occur instantly but through three main stages that are interrelated: contextual meaning-making, conceptual transformation, and analytical articulation. Each stage reflects the dynamics of students' thinking triggered by the narrative and illustrations in the culturally rich comics. In the first stage, contextual meaning-making, students showed a tendency to relate the stories in the comics to their real-life experiences. The environment and culture reflected in the stories of the characters in Longbumbung village are considered familiar and represent social conditions known to students. In group discussions and written reflections, students revealed that stories about traditional kitchens, the use of firewood, and family habits in saving energy were not just story elements, but also opened up space for reflecting on physics concepts that had previously felt abstract. Comics act as a

semantic bridge connecting cultural language with scientific language. This aligns with the view that contextual representation has the power to form initial cognitive schemas that facilitate the integration of new knowledge (Ali & Zaini, 2023; Erlangga et al., 2021, 2024; Qisthi et al., 2025; Wulandari et al., 2023).

The second stage identified was conceptual transformation, in which students began to shift their focus from the story to conceptual analysis. This process was evident when they began to identify thermal phenomena in the story and relate them to the principles of thermodynamics they had learned in class. For example, when a character in a comic describes how water boils longer when the wind blows strongly from the west, students do not simply record this as a cultural fact, but connect it to changes in pressure, heat transfer, and energy efficiency. They begin to make inferences, compare different situations, and question the scientific reasons behind the event. This process demonstrates that students are not merely absorbing information but are beginning to construct arguments and organise knowledge based on scientific principles. This is where cultural narratives serve as a catalyst for stimulating higher-order cognitive elaboration.

According to social constructivism theory, learning experiences based on cultural meaning interactions enable the internalisation of concepts through the proximal development zone, where students form understanding through the help of meaningful representations (Peinado, 2024; Simms, 2024). The final stage, analytical articulation, is characterised by students' ability to present structured scientific arguments, integrate contextual data with formal concepts, and construct logical interpretations of events in comics. Students begin to use scientific terms appropriately, construct cause-and-effect diagrams, and compare the effectiveness of various heat transfer systems based on illustrations in comics. Some students even demonstrate hypothetical-deductive thinking, where they formulate alternative hypotheses about scenes in the comic and explain possible different outcomes if initial conditions are altered. This indicates that comic media are not merely visual aids but also tools for internalising scientific logic.

The findings of this study clearly confirm that the integration of local culture into learning media cannot be understood merely as a decorative element or cosmetic addition that serves to beautify the appearance or give a local flavour to the material. Instead, culture functions as a semantic and symbolic structure that is capable of activating students' cognitive representation systems, forming a conceptual bridge between their life experiences and the scientific concepts studied in class. In the context of the Longbumbung Series comics, local culture is not merely present as a backdrop to the story but becomes the centre of reasoning activities: it fills the narrative plot, shapes characters, influences the actions of the characters, and implicitly carries epistemic values that resonate with the scientific framework of thinking (Tilak et al., 2024).

The presence of cultural elements in comics facilitates the internalisation of scientific meaning through a non-linear, layered and contextual pathway. Students do not begin their learning process with scientific definitions or physical laws, but rather with an introduction to familiar and personally meaningful cultural situations. They enter the story, engage in narrative conflicts or dialogues, and only then gradually build scientific awareness of what is happening. This process is crucial because it demonstrates that scientific understanding does not necessarily originate from theoretical formulations but can emerge from meaningful, narratively structured experiences. Thus, culture not only serves as a vehicle for unlocking meaning but also acts as a medium for testing and critically reflecting on that meaning.

In this study, it was found that when students recognised cultural elements in stories, they felt more emotionally and cognitively involved (Maspatella et al., 2023; Thomson & Cleary, 2024). The sense of familiarity evoked by cultural elements reduces the

epistemological barriers that typically arise when dealing with abstract concepts such as conduction, entropy, or heat efficiency. Even students who initially struggled to understand these concepts in academic texts became more open to discussing them when the concepts appeared implicitly in stories they understood culturally. In other words, comics based on local culture work simultaneously on two dimensions: they build meaning contextually and at the same time challenge students to engage in scientific elaboration and evaluation. Furthermore, the success of the Longbumbung Series in stimulating the development of students' analytical abilities shows that narrative-based learning media have transformative power in science education, especially in complex, abstract, and theoretical subjects such as thermodynamics. In traditional learning processes, concepts such as the laws of thermodynamics are often presented in the form of formulas and verbal-logical explanations that are disconnected from the real-life context of students (Mutiaraningrum et al., 2024; Ragonis et al., 2025). As a result, the learning process tends to become mechanical and lacks reflection. Culture-based comics address this weakness by presenting material in an integrated manner, where scientific concepts and everyday life are presented in a single narrative that can be followed and understood meaningfully. This opens up opportunities to design science learning that is not only transactional but also transformational, fostering conceptual understanding and reflective awareness in students.

The cognitive process of students in this study appeared to develop gradually, starting from the stage of contextual meaning, to conceptual identification, to analytical articulation. In the initial stage, students interpreted stories based on their personal experiences with cultural elements raised in the stories (Baharullah et al., 2022; Honra, 2025). After feeling emotionally involved, they began to recognise the physical phenomena implied in the illustrations or storylines. From this point, they developed a tendency to interpret, infer, and critically evaluate the events described, which ultimately shaped their ability to formulate arguments and explain scientific concepts independently. This process demonstrates that the use of culturally based narrative media contributes not only to the cognitive dimension but also to the metacognitive and epistemological dimensions of science learning.

On the other hand, learning with comics also creates a more humanistic and inclusive atmosphere. Students from diverse socioeconomic and cultural backgrounds feel that they are "involved" in the material, rather than simply "presented" with concepts. This is important in the context of higher education in Indonesia, which often faces challenges in reaching students with diverse experiences. Media such as the Longbumbung Series provide opportunities for the emergence of a more democratic and down-to-earth education, where every student has the opportunity to build knowledge starting from their own point of meaning. Thus, the results of this study imply that the integration of local culture into the design of learning media, if done conceptually and pedagogically, can be a very effective strategy in improving the quality of science learning in higher education. It not only brings to life previously dry and theoretical teaching materials but also revitalises students' thinking processes: from passive and mechanistic to active, reflective, and contextual. Comics like the Longbumbung Series are not merely visual innovations but also representations of a new pedagogical approach that is more context-aware, process-oriented, and values students' ways of thinking as the foundation for meaningful science learning.

CONCLUSION

This study shows that comics based on local culture, such as the Longbumbung Series, not only function as an alternative medium in science learning but also as a pedagogical instrument capable of mediating and enriching students' cognitive processes in a meaningful way. The integration of cultural elements into the narrative and illustrations of comics has been

proven to encourage students to build conceptual understanding through contextual, reflective, and analytical pathways. Culture in this context is not merely superficial or decorative but serves as a representational structure that triggers the activation of scientific reasoning, helping students connect everyday experiences with thermodynamic principles, and strengthening the internalisation of abstract concepts.

These findings also confirm that meaningful science learning is not solely determined by the complexity of the content, but by the way it is presented in a way that bridges the scientific world with the everyday world of students. When learning is delivered in a narrative, visual, and culturally relevant format, students demonstrate a higher tendency to engage in higher-order thinking activities such as interpretation, inference, and conceptual evaluation. Thus, this approach makes an important contribution to the design of science learning that is not only transactional and informative, but also transformative and reflective.

More broadly, this study implies that the use of cultural narrative-based media has great potential to bring the world of science closer to the local context, increase the relevance of learning, and encourage the emergence of pedagogical strategies that are more adaptive to students' ways of thinking. In the future, the development of science learning media based on local cultural values can be one of the key strategies in building scientific literacy rooted in the context and real lives of students. This research encourages educators and curriculum developers to be more daring in exploring narrative-visual approaches rooted in culture as part of educational innovation in higher education.

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