JPII 15 (1) (2026) 40-50

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

STUDENT-GENERATED CONCEPT CARTOONS AS MULTIMODAL LEARNING TOOLS FOR CONCEPTUAL UNDERSTANDING IN PRIMARY SCIENCE EDUCATION: A CASE STUDY FROM TÜRKİYE

E. Gürhan[1] & M. Sholeh[2]

[1]Ministry of National Education, Konya, Türkiye,
[2]Elementary School Teacher Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung, Indonesia

DOI: 10.15294/jpii.v15i1.38186

Accepted: December 7th, 2025. Approved: March 24th, 2026. Published: March 24th, 2026

ABSTRACT

Persistent misconceptions in force and motion continue to challenge conceptual understanding in primary science education, particularly within teacher-centered learning contexts that limit students' epistemic agency. Although researchers widely use concept cartoons to stimulate discussion, most studies focus on teacher-generated materials and rarely explore the pedagogical potential of student-generated concept cartoons. This study investigates how student-authored concept cartoons function as multimodal learning tools to promote conceptual change among fourth-grade students. This study employed a mixed-methods case study with an embedded quasi-experimental design in a public primary school in western Türkiye, involving 30 students assigned to an experimental group and a comparison group receiving conventional learning. Quantitative pre- and post-test data were analyzed using inferential statistics and effect size calculations. The study thematically analyzed qualitative data from student-generated artifacts, classroom observations, and interviews using a multimodal representation framework. The findings revealed a statistically significant improvement in the experimental group's conceptual understanding, with a large effect size (Cohen's d = 1.89), alongside marked gains in visual representational accuracy and dialogic reasoning. These results indicate that learning improvements stemmed not merely from visual exposure but from students' active authorship and negotiation of scientific representations. The study concludes that student-generated concept cartoons serve as effective learning and formative assessment tools, supporting student-centered multimodal pedagogy aligned with SDG 4 and current curriculum reform initiatives in Türkiye.

Keywords: concept cartoons; primary science education; multimodal learning; conceptual understanding

INTRODUCTION

Improving the quality of science education remains a global priority aligned with Sustainable Development Goal 4, which emphasizes inclusive, equitable, and effective learning outcomes (Novitasari et al., 2025; Rosyidah et al., 2025; Widiasih et al., 2025). In primary education, science learning plays a pivotal role in shaping foundational conceptual understanding, scientific reasoning, and epistemic practices essential for lifelong learning (Pollmeier et al., 2017; Van Eijck et al., 2025; Morais et al., 2026). Despite ongoing curriculum reforms and technological integration, persistent challenges continue to limit students' deep conceptual development in core scientific domains. Among these domains, foundational physics concepts remain particularly problematic in early schooling.

One of the most consistently reported areas of difficulty concerns students' understanding of force and motion. These concepts are inherently abstract and require students to reconcile intuitive everyday experiences with formal scientific

*Correspondence Address
E-mail: ethemgurhan@gmail.com

principles. Research indicates that students frequently struggle to grasp the relationship between force and changes in motion, especially when distinguishing between balanced and unbalanced forces (Ecevit & Şimşek, 2017; Resbiantoro & Setiani, 2022). Such difficulties reflect not merely gaps in knowledge but deeper tensions between experiential reasoning and scientific explanation.

Students often equate force directly with motion, assume that motion requires a continuous internal force, or misinterpret the direction and magnitude of interacting forces. These misconceptions constitute coherent alternative explanatory frameworks rather than isolated factual errors. Because such frameworks are grounded in everyday experience, they tend to be stable and resistant to superficial learning correction (Resbiantoro & Setiani, 2022). These persistent patterns raise critical questions about the effectiveness of prevailing learning approaches in facilitating genuine conceptual restructuring.

However, conventional teacher-centered learning has demonstrated limited effectiveness in transforming these entrenched frameworks. Explanation-driven pedagogy and textbook-oriented exercises frequently emphasize correct answers rather than conceptual reorganization (Bachri et al., 2023; Dila et al., 2025; Ubaidillah et al., 2025). Although students may memorize terminology or reproduce definitions, their underlying reasoning structures often remain unchanged. This misalignment between learning practice and conceptual transformation suggests the need for approaches that engage students more actively in reconstructing their understanding.

Outcome-oriented assessment practices further compound the problem. Traditional assessments tend to privilege final responses over reasoning processes, thereby obscuring the persistence of alternative conceptions. Consequently, misconceptions may remain undetected even when students achieve acceptable scores (Jeppsson et al., 2022; Danielsson et al., 2023). Addressing these intertwined learning and assessment limitations demands a theoretically grounded framework that explains how conceptual transformation occurs and how teachers can support it in classroom contexts.

Conceptual change theory offers such a foundation by positing that meaningful learning occurs when students encounter cognitive conflict, critically evaluate prior beliefs, and reorganize their conceptual structures into more scientifically coherent forms. However, contemporary research emphasizes that conceptual change is not solely an internal cognitive process. Instead, discourse, interaction, and representational activities actively mediate the construction of knowledge (Jeppsson et al., 2022; Danielsson et al., 2023). Opportunities to articulate, confront, and negotiate explanations, therefore, become central to sustained conceptual transformation.

While conceptual change theory explains the restructuring of prior knowledge, multimodal learning theory extends this account by emphasizing how coordinated representational practices mediate conceptual restructuring. Multimodal learning theory argues that students construct scientific meaning by orchestrating multiple semiotic resources, including visual, textual, symbolic, and dialogic modes. Representational competence, defined as the ability to generate, interpret, and refine scientific representations, plays a crucial role in developing coherent understanding (Jeppsson et al., 2022; Danielsson et al., 2023). When students actively coordinate these modes to externalize and reorganize their thinking, conceptual transformation becomes both cognitively and socially mediated. Integrating conceptual change with multimodal representation, therefore, provides a coherent theoretical pathway for addressing persistent misconceptions in primary science.

An learning strategy that operationalizes these complementary principles is the use of concept cartoons. Concept cartoons present alternative viewpoints through illustrated characters and dialogic exchanges, encouraging students to evaluate competing explanations (Keogh & Naylor, 1999; Evrekli & Balım, 2024). Empirical studies indicate that teacher-generated concept cartoons can enhance engagement, stimulate argumentation, and improve learning outcomes across science contexts (Muamber, 2020; Asare et al., 2022; Eryilmaz & Bozgün, 2022; Zivanayi & Nwaigwe, 2024). Despite these positive findings, most implementations position students as interpreters of pre-designed representations rather than as creators of scientific meaning.

This teacher-generated paradigm reveals a critical gap in both theoretical and empirical grounds. If representational construction and dialogic negotiation mediate conceptual change, positioning students as authors of scientific representations may offer a more powerful mechanism for supporting learning. However, limited empirical research has examined student-generated concept cartoons as multimodal artifacts through which students externalize, interrogate, and revise their explanatory frameworks (Demirci, 2017; Szarková, 2017; Altiner, 2024; Abrahams, 2025). Moreover, prior studies have predominantly emphasized achievement outcomes while paying insufficient attention to representational processes and epistemic negotiation (Pekel, 2019; Wusqo et al., 2021; Fadhilah & Nurmalasari, 2025). As a result, the epistemic function of student authorship in facilitating conceptual change remains under-theorized.

Preliminary classroom observations conducted prior to this study further substantiate this concern. Although many fourth-grade students could recall key terminology related to force and motion, they struggled to translate these concepts into coherent visual and dialogic representations. Their drawings frequently lacked accurate indicators of force direction or magnitude, and peer discussions often relied on everyday reasoning rather than scientific justification. These patterns suggest that conceptual understanding may remain fragmented when opportunities for multimodal authorship and dialogic refinement are limited.

In response to this theoretical and empirical gap, the present study investigates student-generated concept cartoons as a pedagogical mechanism that integrates conceptual change and multimodal learning. Specifically, this study examines changes in students' conceptual understanding of force and motion following engagement in student-generated concept cartoon activities, analyzes how students construct and refine multimodal scientific representations through self-authored concept cartoons, and explores patterns of peer dialogue and epistemic negotiation that emerge during these activities. By integrating quantitative measures of learning gains with qualitative multimodal analysis, this study positions student authorship as an epistemic mechanism in conceptual change. It advances a representation-driven, student-centered model of primary science learning aligned with SDG 4 and contemporary curriculum reform initiatives in Türkiye.

METHODS

This study employed a mixed-methods case study with an embedded quasi-experimental design in Türkiye to examine the effectiveness of student-generated concept cartoons in improving primary school students' conceptual understanding of force and motion. The qualitative component explored how students constructed and represented scientific ideas through visual artifacts, while the quantitative component measured changes in conceptual understanding before and after the intervention.

This study took place during regular science learning at a public primary school in western Türkiye. It involved 30 fourth-grade students, with fifteen assigned to the experimental group that participated in student-generated concept cartoon activities. In comparison, the remaining fifteen students formed the comparison group and received conventional teacher-centered learning on the same topics. Both groups were taught within the same school context, followed an identical curriculum objectives, and received learning over the same duration to ensure comparability between conditions.

This study focused on learning effectiveness within a specific classroom context rather than statistical generalization. Therefore, the researchers employed effect-size analysis to emphasize the magnitude of learning gains resulting from the intervention, consistent with previous educational research using small-scale classroom-based designs (Cohen, 2013). Prior to the intervention, the researchers conducted classroom observations and informal interviews to identify students' initial understanding and common misconceptions related to force and motion. These findings informed the design of the concept cartoon activities and ensured alignment with students' prior knowledge. These findings informed the design of the concept cartoon activities and ensured alignment with students' prior knowledge.

The intervention took place over two learning sessions. Students in the experimental group worked in pairs to create their own concept cartoons based on everyday phenomena involving force and motion. In the first session, they discussed initial ideas. They drafted cartoons presenting alternative explanations, using directional arrows to represent forces, labels to identify force types (push, pull, friction), and speech bubbles to express differing viewpoints. In the second session, pairs exchanged drafts. They engaged in structured peer discussion to evaluate the accuracy of force direction, magnitude, and causal relationships, while the teacher provided scaffolding through guided questioning and prompts requiring scientific justification. Students then revised their cartoons to improve conceptual accuracy and coherence between visual and textual elements. The activities emphasized cognitive conflict, dialogic reasoning, and multimodal representation (Keogh & Naylor, 1999). The control group received teacher-centered learning using textbooks and explanation-based activities without student-generated visual representations.

Data collection employed multiple instruments. Qualitative data consisted of student-generated concept cartoons, classroom observation notes, and semi-structured interviews with selected students. Quantitative data were collected using a 20-item conceptual understanding test administered as a pre-test and post-test to both groups. The test consisted of multiple-choice and short explanatory items designed to assess students' understanding of key subtopics in the force and motion unit, including types of forces (push, pull, and friction), direction and magnitude of force, balanced and unbalanced forces, and the relationship between force and changes in motion such as starting, stopping, and changing speed or direction.

The researchers developed the test items based on the national science curriculum and informed them with prior studies that identified common misconceptions in force and motion (Halloun & Hestenes, 1985; Treagust, 1988). These studies consistently show that students often hold persistent alternative conceptions regarding fundamental physics principles, particularly in Newtonian mechanics. In science education research, scholars widely use several diagnostic instruments to identify such misconceptions, including the Certainty of Response Index (CRI), two-tier tests, and three-tier diagnostic tests (Hasan et al., 1999; Gurel et al., 2015). These instruments capture not only students' answers but also their reasoning and confidence levels, enabling researchers to diagnose the structure of misconceptions.

To ensure content validity, two science education experts reviewed the test items to evaluate their alignment with the intended learning concepts. A pilot test was conducted prior to the main data collection to assess the instrument's reliability. The reliability analysis showed satisfactory internal consistency, with a Cronbach's alpha coefficient of $\alpha = 0.82$, indicating that the instrument was reliable for measuring students' conceptual understanding. Qualitative data were analyzed using thematic content analysis to identify patterns in representational accuracy, scientific terminology, and reasoning processes (Mayring, 2000). This study applied a multimodal representation framework to examine the integration of visual, textual, and dialogic elements in students' cartoons (Reid & Moses, 2022).

The study analyzed quantitative data using descriptive statistics and inferential analysis to compare pre-test and post-test results between groups. It calculated Cohen's d to assess the learning impact of student-generated concept cartoons. By integrating quantitative measures of learning gains with qualitative analyses of student-generated representations and peer dialogue, this fixed-methods design aimed to explain not only the intervention's effectiveness but also the underlying learning processes that contributed to conceptual change.

The researchers obtained ethical approval from the school authorities and secured parental consent prior to data collection. They anonymized all student identities to ensure confidentiality and followed ethical standards for educational research involving children. Figure 1 illustrates the overall research procedure, including participant assignment, intervention stages, data collection, analysis, and integration.

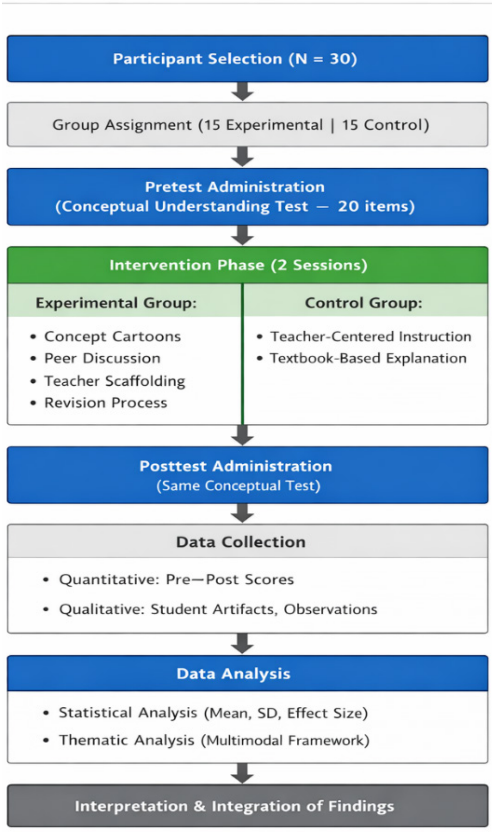

Figure 1. Research Design Flowchart of the Embedded Mixed-Methods Study

RESULTS AND DISCUSSION

This subsection presents the quantitative findings on students' conceptual understanding of force and motion following the two-session student-generated concept cartoon intervention, which included structured peer discussion, teacher scaffolding, and iterative revision of visual representations. The analysis compares pre-test and post-test results between the experimental group and the control group, who received conventional teacher-centered learning. Table 1 summarizes the pre-test and post-test results of the experimental and control groups.

Table 1. Students' Conceptual Understanding Scores (Pretest vs Posttest)

Group	Pretest Mean (SD)	Posttest Mean (SD)	Δ Mean	pvalue	Effect Size (Cohen's d)
Experimental (StudentGenerated Cartoons)	42.1 (8.7)	68.4 (7.9)	+26.3	< .001	1.89
Control (Traditional Learning)	41.8 (9.2)	52.7 (8.3)	+10.9	.023	0.53

As shown in Table 1, students in the experimental group demonstrated a substantial improvement in conceptual understanding after the intervention. The mean score increased from 42.1 (SD = 8.7) in the pre-test to 68.4 (SD = 7.9) in the post-test, resulting in a mean gain of 26.3 points. In contrast, the control group exhibited a more modest improvement, with mean scores increasing from 41.8 (SD = 9.2) to 52.7 (SD = 8.3).

Inferential analysis revealed a statistically significant difference between the post-test scores of the experimental and control groups ($p < .001$). The results indicate a substantial difference, reflected in a large effect size (Cohen's d = 1.89) based on post-test scores. Although the effect size is large, the study interprets it in the context of a small-scale classroom intervention.

This finding suggests that student-generated concept cartoons had a substantial impact on students' understanding of force and motion (Muamber, 2020; Song, 2021; Asare et al., 2022; Eryilmaz & Bozgün, 2022; Evrekli & Balım, 2024; Zivanayi & Nwaigwe, 2024; Kumi-Manu et al., 2025). However, the present findings significantly extend earlier research. While most prior studies relied on teacher-generated or researcher-designed concept cartoons, this study demonstrates that student-authored visual representations can yield stronger learning outcomes by actively engaging students in constructing and externalizing their scientific reasoning. To ensure conceptual accuracy, the cartoon development process was supported by structured peer review and teacher scaffolding, including guided questioning, prompts requiring scientific justification, and whole-class reflection sessions. These mechanisms enabled misconceptions to be identified, discussed, and revised before final submission, thereby aligning students' representations with scientifically accepted explanations.

From a conceptual perspective, the large effect size observed in this study supports arguments from multimodal learning research that learning is strengthened when students integrate visual, verbal, and contextual resources to represent scientific ideas (Muamber, 2020; Jeppsson et al., 2022; Danielsson et al., 2023). By generating their own cartoons, students actively determined how to represent, label, and explain forces in specific contexts, rather than merely recalling scientific terms. This process required coordination between visual symbols, scientific language, and conceptual relationships, thereby promoting deeper cognitive processing and more coherent scientific understanding.

The contrast between the experimental and control groups highlights the limitations of conventional learning in addressing persistent misconceptions related to force and motion. Previous reviews have shown that such misconceptions are resistant to change when learning focuses primarily on explanation and textbook-based activities (Resbiantoro & Setiani, 2022; Atchia & Gunowa, 2024; Ergin et al., 2025). The findings of the present study suggest that student-generated concept cartoons can function as an effective alternative by making students' thinking visible and open to discussion, which is essential for conceptual change.

Taken together, these results indicate that improvements in conceptual understanding were not merely a result of exposure to visual materials but rather stemmed from students' active involvement in authoring and negotiating scientific representations. This distinction reinforces the pedagogical value of student-generated concept cartoons as a student-centered strategy for improving conceptual understanding in primary science education.

This subsection examines changes in students' visual representations of force and motion as reflected in their self-generated concept cartoons. Table 2 presents the quantitative coding results for key representational features observed before and after the intervention, including engagement in the concept cartoon activities.

Table 2. Quantitative Coding Results

Feature	Pre (%)	Post (%)	Change (%)
Accurate Representation of Force	22	66	+44
Use of Explanatory Captions	18	74	+56
Evidence of Reasoning Dialogue	12	58	+46

As shown in Table 2, students demonstrated substantial improvement in their ability to visually represent scientific concepts. The proportion of cartoons accurately depicting force direction increased from 22% in the pre-intervention phase to 66% after the intervention. Similarly, the use of explanatory captions and dialogic elements increased markedly, indicating growth in students' ability to externalize and communicate scientific reasoning.

These improvements suggest a development in students' representational competence, particularly in integrating visual, textual, and dialogic resources to express scientific ideas. Specifically, students increasingly coordinated directional arrows with accurate force labels and explanatory captions while using dialogue in speech bubbles to articulate causal relationships between force and motion. This integration indicates that students were not merely adding visual elements, but systematically aligning symbolic, linguistic, and conceptual components to construct more coherent scientific explanations. Previous studies have emphasized that students' drawings and visual artifacts can serve as powerful indicators of conceptual understanding when students are actively involved in constructing representations rather than passively interpreting them (Jeppsson et al., 2022; Danielsson et al., 2023).

The present findings support this view by showing that student-generated concept cartoons facilitated more accurate and meaningful visual explanations of force and motion concepts. The cartoons addressed the core subtopics of the learning unit, namely types of forces (push, pull, and friction), the direction and magnitude of force, and the relationship between force and changes in motion (starting, stopping, and changing speed or direction). This comprehensive coverage ensured alignment between the learning activities and the targeted curriculum objectives.

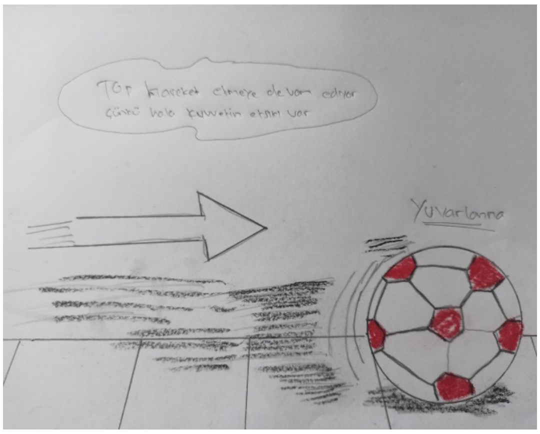

Figure 2. Rolling Ball Motion Demonstrating the Effect of Friction on Movement

The inclusion of directional cues and scientific terminology reflects emerging conceptual awareness, although some representations remained descriptive rather than mechanistic. This pattern is consistent with findings reported by Chin & Teou (2009), who noted that visual representations often reveal partial understanding that teachers can further refine through guided discussion.

Students depicted combined push and pull forces in a realistic scenario. The use of action-based dialogue and coordinated movement suggests an intuitive understanding that increased applied force can influence motion. Bachri et al. (2023), Chang et al. (2025), and Lamminpää et al. (2023) reported similar trends, finding that student-generated visual models support explanatory reasoning even when students do not explicitly articulate formal quantitative relationships.

Notably, the observed improvements in visual representation extended beyond surface features, such as labeling. Also, they reflected changes in how students structured their explanations and in their understanding of relationships between forces and motion. This finding reinforces arguments that student-generated representations function as formative assessment tools, enabling teachers to identify both conceptual progress and remaining misconceptions (Danielsson et al., 2023; Muslim et al., 2024; Genç & Aksoy, 2025).

Overall, these results indicate that engaging students in authoring their own concept cartoons supported the development of visual scientific representation skills. From a multimodal learning perspective, the activity required students to coordinate multiple semiotic modes, including visual symbols such as arrows and diagrams, written labels, and dialogic text, into a coherent representation of force and motion. This coordinated integration of modes reflects the development of representational competence, as students aligned symbolic, linguistic, and conceptual resources to construct scientifically meaningful explanations beyond conventional learning.

This subsection examines how peer dialogue and collaborative reasoning emerged during the student-generated concept cartoon activities. To capture patterns of classroom interaction, students' discourse was analyzed and coded based on dialogic features related to scientific reasoning. Table 3 presents the distribution of coded peer discourse categories observed during the intervention.

Table 3. Distribution of Peer Discourse Codes During Concept Cartoon Activities

Discourse Category	Percentage of Coded Interactions (%)
Argumentation about Predictions	34
Negotiation of Meaning	41
Reference to Evidence	27

Note: Percentages represent the proportion of coded discourse segments identified during peer interactions. A single interaction may include more than one discourse category; therefore, the total percentage may exceed 100%

As shown in Table 3, negotiation of meaning was the most frequently observed discourse category, followed by argumentation about predictions and references to evidence. This distribution indicates that a substantial proportion of students were actively engaged in discussing, questioning, and refining their ideas rather than merely completing the assigned tasks. While participation levels varied across pairs, most students contributed to the negotiation of meaning and collaborative reasoning during the activities. Such interaction patterns suggest that the concept cartoon activities fostered a dialogic learning environment conducive to conceptual development.

The prominence of meaning negotiation highlights the role of peer interaction in supporting students' understanding of abstract science concepts. Through discussion, students articulated their initial ideas, encountered alternative viewpoints, and collaboratively resolved conceptual disagreements. This finding aligns with previous research emphasizing that dialogic interaction plays a critical role in knowledge construction and conceptual change in science learning (Chin & Teou, 2009; Atasoy et al., 2022; Lamminpää et al., 2023; Walid et al., 2023; Atchia & Gunowa, 2024; Muslim et al., 2024).

Figure 3. Push and Pull Force Collaboration in Everyday Context

As illustrated in Figure 3, A student-generated cartoon shows a child pushing a box onto a small cart. In contrast, another child pulls the cart forward, with directional arrows illustrating how push and pull forces work together to move the load across the floor. While these representations supported engagement and narrative coherence, they occasionally reflected ambiguity in causal reasoning, particularly regarding the direction and magnitude of force and the relationship between force and motion. For example, in Figure 2, a cartoon depicting a ball rolling on the ground, a student wrote, "*Top hareket etmeye devam ediyor çünkü hala kuvvetin etkisi var*" as "The ball keeps moving because the force is still inside it," indicating a misconception that force is an internal property rather than an interaction. In another case, students drew arrows in multiple directions without distinguishing between balanced and unbalanced forces, suggesting confusion about net force and motion change. These examples illustrate how simple narrative and visual elements in the cartoons stimulated discussion while revealing common misconceptions about push, pull, and friction, which were subsequently addressed through guided peer dialogue and teacher scaffolding (Pekel, 2019; Lamminpää et al., 2023).

Notably, references to evidence within peer dialogue, although less frequent, indicate emerging scientific reasoning practices. This study identified instances in which students justified their claims by referring to observable phenomena, prior classroom demonstrations, or specific elements in their drawings, such as arrow directions or object positions. For example, Figure 3 some students stated, *"Kutu sağa doğru hareket ediyor çünkü sağa doğru itme kuvveti daha güçlü"* as *"The box moves to the right because the push arrow is stronger,"* or referred to a previous experiment by saying, *"Eğer daha güçlü itersek kutu daha hızlı hareket eder"* as *"When we pushed harder in class, it moved faster."* Such statements were coded as evidence-based reasoning because they linked claims to observable phenomena or representations rather than to opinion. Students began to justify their claims by referring to observable phenomena, prior experiences, or features depicted in their drawings. This progression reflects an early form of argumentation, consistent with findings by ALjrah et al. (2021), Atasoy et al. (2022), Ceylan & Yiğit (2018), Muslim et al. (2024), and Strande & Madsen (2018), who noted that student-generated multimodal representations can support the externalization of reasoning processes in science classrooms.

Overall, the analysis of peer discourse demonstrates that student-generated concept cartoons did more than support individual understanding; they also facilitated collaborative reasoning and meaningful scientific dialogue. By integrating visual representation with peer discussion, the activity created opportunities for students to negotiate meaning, challenge misconceptions, and refine their explanations, thereby contributing to deeper conceptual understanding.

The integrated analysis of quantitative and qualitative findings provides a coherent explanation of how student-generated concept cartoons supported learning in primary science education. Improvements in students' conceptual understanding, as evidenced by the large effect size in Table 1, were accompanied by qualitative changes in visual representations (Table 2) and peer discourse patterns (Table 3). This convergence of outcomes across multiple analytical levels strengthens the validity of the findings.

The substantial learning gains observed in the experimental group cannot be attributed solely to exposure to visual materials. Instead, they reflect students' active engagement in authoring, discussing, and revising their own scientific representations. Studies show that concept cartoons not only help identify and address students' misconceptions but also encourage active engagement through discussion, argumentation, and reflection with peers, thereby strengthening the constructivist learning process (Finbråten et al., 2022; Önal, 2023). In addition, students who learn with this method tend to be more motivated and show greater interest in science lessons than those who learn with conventional methods (Muamber, 2020).

The alignment between improved visual representations and increased dialogic interaction suggests a reciprocal relationship between representation and reasoning (Robson, 2019; Kendall et al., 2020). As students refined their drawings, they simultaneously engaged in negotiation of meaning and argumentation with peers, which contributed to resolving misconceptions and developing more coherent scientific explanations.

From a pedagogical standpoint, these findings highlight the dual function of student-generated concept cartoons as both learning tools and formative assessment instruments. The visual and dialogic artifacts produced by students provided teachers with immediate insights into students' thinking, enabling them to identify conceptual progress and remaining misunderstandings. Such multimodal meaning-making processes are widely recognized as supporting deeper learning in science education (Şanlıtürk & Zeybek, 2022; Danielsson et al., 2023; Siregar et al., 2023; Zivanayi & Nwaigwe, 2024).

In addition, the findings have broader relevance for curriculum initiatives that emphasize creativity, visual literacy, and inquiry-based learning in primary science education. The use of student-generated concept cartoons aligns with curricular orientations that promote active knowledge construction, multimodal expression, and the integration of scientific concepts with everyday experiences. However, implementing this approach is not without challenges. Effective facilitation requires teachers to possess sufficient pedagogical and content knowledge to guide discussions, identify misconceptions, and provide timely scaffolding. Teacher mediation in such student-centered activities is contextually bounded and shaped by structural conditions, including workload and institutional expectations (Gürhan, 2026). Without structured guidance, student-generated representations may reinforce rather than correct misunderstandings, particularly regarding the direction, magnitude, and causal mechanisms of force. Furthermore, variations in classroom dynamics, including students' psychosocial backgrounds and documented adaptation challenges in Turkish primary schools (Gürhan, 2025), may affect the consistency of learning outcomes. These considerations suggest that while student-generated concept cartoons offer strong pedagogical potential, their effectiveness depends on careful learning design and informed teacher mediation.

These findings have practical implications for primary science teachers and curriculum designers. Integrating student-generated visual representations into regular learning may enhance both formative assessment practices and conceptual transparency in classrooms. Professional development programs may also consider incorporating training on multimodal scaffolding strategies to support effective implementation.

Overall, the integrated findings demonstrate that student-generated concept cartoons offer a student-centered approach that connects conceptual understanding, representational competence, and collaborative reasoning. By engaging students in multimodal meaning-making processes, this approach offers a practical, adaptable strategy for enhancing science learning in primary education settings. However, there are several limitations when interpreting these findings, including the relatively small sample drawn from a single school context, the short duration of the intervention, and the absence of longitudinal data on the retention of conceptual change. Future research should involve larger, more diverse samples, extend the duration of implementation, and examine the long-term and cross-disciplinary applicability of student-generated multimodal representations to further strengthen their theoretical and practical implications. These findings suggest that positioning students as epistemic authors within multimodal learning environments offers a promising approach to strengthening conceptual change in primary science education

CONCLUSION

This study concludes that student-generated concept cartoons are an effective learning tool for enhancing primary school students' conceptual understanding of force and motion. Unlike traditional methods that use pre-designed visuals, this approach empowers students to actively construct and express their scientific knowledge through visual and verbal elements. The findings indicate that when students are allowed to author their own representations, they demonstrate improved scientific reasoning, more accurate use of terminology, and deeper engagement with core concepts. This study supports the idea that multimodal, student-centered strategies not only reveal student thinking but also promote meaningful learning and conceptual change.

REFERENCES

Abrahams, W. (2025). Enhancing South African science education: The impact of concept cartoons on teaching terminology during science investigations in intermediate phase. *Reading & Writing*, *16*(1), a548.

ALjrah, I. M., Legino, R., & Anwar, R. (2021). A multimodal analysis of cartoon in Jordan. *International Journal of Academic Research in Business and Social Sciences*, *11*(9), 521-546.

Altiner, E. Ç. (2024). Exploring measurement estimation strategies through concept cartoons designed with Realistic Mathematics Education. *Humanities & Social Sciences Communications*, *11*(1), 567.

Asare, A. H. Y., Jeremiah, A. M., Ameyaw, F., & Nti, D. (2022). Effect of Concept Cartoons on Kindergarten Pupils' Numeracy and Science Performance in Sagnarigu-Tamale, Ghana. *East African Journal of Education and Social Sciences*, *3*(3), 56–62.

Atasoy, Ş., Tekbıyık, A., Çalık, M., & Tüzün, Ö. Y. (2022). Development of argumentation based concept cartoons for socioscientific issues: A case of science and art centers. *Education and Science*, *47*(211), 323-367.

Atchia, S. M. C., & Gunowa, M. (2024). Use of concept cartoons within the conceptual change model to address students' misconceptions in biology: A case study. *Journal of Biological Education*, 1–19.

Bachri, B. S., Tegeh, M., & Jayanta, I. N. L. (2023). Impact of Phenomenon-Based Learning Model Assisted by Virtual Book-Based Digital Comics on Elementary-School Students' Agile Innovation and Independence in Science Learning. *Jurnal Pendidikan IPA Indonesia*, *12*(3), 493–503.

Ceylan, Ö., & Yiğit, E. A. (2018). Analyzing the Effect of Concept Cartoon Usage on Students' Cognitive Structures Developments and Science Achievements through Flow Maps. *Science Education International*, *29*(4), 238–249.

Chang, J., Park, J., Yoon, H. G., Park, J., & Ha, M. (2025). The features of visual models generated by primary school students in an online learning platform. *International Journal of Science Education*, 1–21.

Chin, C., & Teou, L. (2009). Using Concept Cartoons in Formative Assessment: Scaffolding students' argumentation. *International Journal of Science Education*, *31*(10), 1307–1332.

Cohen, J. (2013). *Statistical Power Analysis for the Behavioral Sciences* (0 ed.). Routledge.

Danielsson, K., Jeppsson, F., Nestlog, E. B., & Tang, K. (2023). Representations of science content in a primary classroom: Combining long and short timescales for multimodal analysis. *Science Education*, *107*(6), 1561–1592.

Demirci, F. (2017). The Effects of Using Concept Cartoons in Astronomy Subjects on Critical Thinking Skills among Seventh Grade Student. *International Electronic Journal of Elementary Education*, *10*(2), 243–254.

Dila, A. S., Shalihah, S., Khairunnisa, K., & Hasanah, M. (2025). The Effect of Practicum-Based Learning on Elementary Students' Achievement in Magnetism. *L-Adzka: Jurnal Ilmiah Pendidikan Guru Madrasah Ibtidaiyah*, *15*(2), 272–281.

Ecevit, T., & Şimşek, P. Ö. (2017). Öğretmenlerin fen kavram öğretimleri, kavram yanılgılarını saptama ve giderme çalışmalarının değerlendirilmesi. *İlköğretim Online*, *16*(1).

Ergin, E., Cakir, C. S., & Durukan, U. G. (2025). The

Impact of the Concept Cartoons and Conceptual Change Texts on 7th Grade Students' Understanding of "Space Exploration". *MIER Journal of Educational Studies Trends and Practices*, 1-30.

Eryilmaz, Ö., & Bozgün, K. (2022). The Effect of Using Cartoons on Primary School Students' Academic Achievement in Social Studies Courses in Turkey: A Meta Analysis Study. *Human, Technologies and Quality of Education, 2022*, 686–697.

Evrekli, E., & Balım, A. G. (2024). The Effect of Using Animated Concept Cartoons in Science Education on Student's Conceptual Understanding. *Manisa Celal Bayar Üniversitesi Eğitim Fakültesi Dergisi*, *12*(2), 414–436.

Fadhilah, M., & Nurmalasari, G. (2025). The Effectiveness of Using Wordwall Media on Student Learning Interest IPAS at Madrasah Ibtidaiyah. *Journal of Elementary Education Research and Practice*, *1*(2), 85–91.

Finbråten, H. S., Grønlien, H. K., Pettersen, K. S., Foss, C., & Guttersrud, Ø. (2022). Nursing students' experiences with concept cartoons as an active learning strategy for developing conceptual understanding in anatomy and physiology: A mixed-method study. *Nurse Education in Practice*, *65*, 103493.

Genç, H. N., & Aksoy, A. C. A. (2025). Elimination of Pre-service Science Teachers' Misconceptions about Change of State; The Role of Concept Cartoons. *E-Kafkas Eğitim Araştırmaları Dergisi*, *12*(2), 527–540.

Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *EURASIA Journal of Mathematics, Science and Technology Education*, *11*(5).

Gürhan, E. (2025). Silent Struggles of Foreign Fourth-Grade Primary School Students: Psychological Resilience and Invisible Traumas in Türkiye. *Al-Adzka: Jurnal Ilmiah Pendidikan Guru Madrasah Ibtidaiyah*, *15*(2), 156–165.

Gürhan, E. (2026). Workload-Mediated Teacher Agency in Curriculum Adaptation: Practice-Based Evidence from Turkish Primary Schools. *Journal of Elementary Education Research and Practice*, *2*(1), 31–45.

Halloun, I. A., & Hestenes, D. (1985). Common sense concepts about motion. *American Journal of Physics*, *53*(11), 1056–1065.

Hasan, S., Bagayoko, D., & Kelley, E. L. (1999). Misconceptions and the Certainty of Response Index (CRI). *Physics Education*, *34*(5), 294–299.

Jeppsson, F., Danielsson, K., Nestlog, E. B., & Tang, K. S. (2022). Primary Pupils' Multimodal Representations in Worksheets—Text Work in Science Education. *Education Sciences*, *12*(3), 221.

Kendall, L. N., Raffaelli, Q., Todd, R. M., Kingstone, A., & Cohn, N. (2020). Show me how you feel: Iconicity and systematicity in visual morphology. In P. Perniss, O. Fischer, & C. Ljungberg (Eds.), *Iconicity in Language and Literature* (Vol. 17, pp. 213–230). John Benjamins Publishing Company.

Keogh, B., & Naylor, S. (1999). Concept cartoons, teaching and learning in science: An evaluation. *International Journal of Science Education*, *21*(4), 431–446.

Kumi-Manu, R. N., Acquah, S., & Eminah, C. (2025). Exploring Junior High School Learners' Motivation in Science Through Concept Cartoon-Based Instruction. *British Journal of Contemporary Education*, *5*(2), 53–73.

Lamminpää, J., Vesterinen, V.-M., & Puutio, K. (2023). Draw-A-Science-Comic: Exploring children's conceptions by drawing a comic about science. *Research in Science & Technological Education*, *41*(1), 39–60.

Mayring, P. (2000). Pensionierung als Krise oder Glücksgewinn? Ergebnisse aus einer quantitativ–qualitativen Längsschnittuntersuchung. *Zeitschrift für Gerontologie und Geriatrie*, *33*(2), 124–133.

Morais, C., Ferreira, A., Araújo, J. L., & Moreira, L. (2026). Chemistry in early childhood: Storytelling and hands-on water-based activities to foster scientific concepts and ideas. *Chemistry Education Research and Practice*, 10.

Muamber, Y. (2020). Impact of instruction with concept cartoons on students academic achievement in science lessons. *Educational Research and Reviews*, *15*(3), 95–103.

Muslim, M., Sihombing, R. A., Zakwandi, R., & Karimi, A. (2024). Evaluating Students' Argumentation Skills Using an Argument-Generating Learning Model Supported Toulmin's Argumentation Pattern in Physics Concepts. *Jurnal Pendidikan IPA Indonesia*, *13*(4).

Novitasari, D., Winanti, Geraldina, I., Asfi, M., Indrajit, E., Hariguna, T., & Natalia, E. A. (2025). Optimizing Educational Technology for Inclusive and Quality Learning Through PLS-SEM Analysis. *2025 4th International Conference on Creative Communication and Innovative Technology (ICCIT)*, 1–7.

Önal, H. (2023). An effective, entertaining and interesting tool to identify students› misconceptions: The concept cartoons. *Southeast Asia Early Childhood Journal*, *12*(2), 20–34.

Pekel, F. O. (2019). Effectiveness of Argumentation-Based Concept Cartoons on Teaching Global Warming, Ozone Layer Depletion, and Acid Rain. *Journal of Environmental Protection and Ecology*, *20*(2), 945–953.

Pollmeier, J., Tröbst, S., Hardy, I., Möller, K., Kleickmann, T., Jurecka, A., & Schwippert, K. (2017). Science-P I: Modeling Conceptual Understanding in Primary School. In D. Leutner, J. Fleischer, J. Grünkorn, & E. Klieme (Eds.), *Competence Assessment in Education* (pp. 9–17). Springer International Publishing.

Reid, S. F., & Moses, L. (2022). One Fourth-Grader's Orchestration of Modes Through Comic Com-position. *Written Communication*, *39*(4), 722–756.

Resbiantoro, G., & Setiani, R. (2022). A Review of Misconception in Physics: The Diagnosis, Causes, and Remediation. *Journal of Turkish Science Education*.

Robson, S. (2019). Young children's visual thinking. In S. Robson, *Developing Thinking and Understanding in Young Children* (3rd ed., pp. 203–214). Routledge.

Rosyidah, F., Susantini, E., Yuliani, Y., & Nisa', K. (2025). Local Wisdom and STEM in Science Education to Support SDG-4: A Systematic Review. *Jurnal Pendidikan IPA Indonesia*, *14*(4).

Şanlıtürk, A. D., & Zeybek, G. (2022). The Effect of Using Digital Concept Cartoons in Science Lesson on Students' Achievement. *Journal of Science Learning*, *5*(1), 1–13.

Siregar, N. F., Sriyati, S., & Amprasto, A. (2023). Implementation of Dialogic Teaching Through Concept Cartoon Worksheets to Improve High School Students' Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 5816–5826.

Song, M. J. (2021). Teacher professional development in integrating digital fabrication technologies into teaching and learning. *Educational Media International*, *58*(4), 317–334.

Strande, A. L., & Madsen, J. (2018). Concept cartoons as teaching method for argumentation and reflection among teacher students and pupils. *Nordic Studies in Science Education*, *14*(2), 170–185.

Szarková, D. (Ed.). (2017). *Observing how future primary school teachers reason and generalize: The case of number triangles and concept cartoons*. Curran Associates, Inc. APLIMAT, Red Hook, NY.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education*, *10*(2), 159–169.

Ubaidillah, S. R., Balqis, A. E., Jannah, B., Maimuna, S., & Fatmawati, E. (2025). Transformation of IPAS Learning in Elementary Schools: The Strategic Role of Digital Media in Improving Students' Understanding. *Journal of Elementary Education Research and Practice*, *1*(2), 92-101.

Van Eijck, T., Bredeweg, B., Holt, J., Pijls, M., Bouwer, A., Hotze, A., Louman, E., Ouchchahd, A., & Sprinkhuizen, M. (2025). Combining hands-on and minds-on learning with interactive diagrams in primary science education. *International Journal of Science Education*, *47*(18), 2413–2433.

Walid, A., Winarni, E. W., & Yanti, F. A. (2023). Argumentation Skill Assessment for Diagnosing Students' Understanding of Factual, Conceptual, Procedural, and Metacognitive Knowledge: Characteristics of Initial Needs. *Jurnal Pendidikan IPA Indonesia*, *12*(1), 14–23.

Widiasih, W., Adji, S. S., Firmansyah, J., Ekawati, R., Sumardani, D., & Chaw, E. P. (2025). Enhancing Student Engagement in Science Practicum in Distance Higher Education for Quality Education (SDG 4). *Jurnal Pendidikan IPA Indonesia*, *14*(1).

Wusqo, I. U., Khusniati, M., Pamelasari, S. D., Laksono, A., & Wulandari, D. (2021). The Effectiveness of Digital Science Scrapbook on Studentsâ€™ Science Visual Literacy. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 121–126.

Zivanayi, W., & Nwaigwe, C. G. C. (2024). Enhancing Formal Assessment Using Concept Cartoons in Physics: A Teacher's Perspective. *Science Education International*, *35*(4), 348–359.