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Developing Interactive Smart Wheel Media to Enhance Conceptual Understanding of Matter State Changes in Elementary School Students

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Abstract: Conceptual understanding is essential in elementary science, yet students often memorize the names of matter state changes without explaining the underlying processes. This study aimed to develop and evaluate Interactive Smart Wheel media for improving fourth-grade students' conceptual understanding of matter state changes. Research and Development was conducted through the ADDIE stages of analysis, design, development, implementation, and evaluation. The local product trial involved 25 fourth-grade students, one classroom teacher, one media validator, and one subject-matter validator at SD Swasta IT Zia Salsabila. Data were collected through classroom observation, interviews, expert-validation sheets, teacher and student response questionnaires, and pretest-posttest concept-understanding tests. The media expert score was 95%, and the material expert score was 90%, indicating high validity. Teacher and student practicality scores were 95.8% and 85.4%, respectively. Students' mean score increased from 42.8 on the pretest to 84.8 on the posttest, with a mean N-Gain of 0.748 in the high category. The study's originality lies in combining a physical rotating wheel, visual representations, QR-linked videos, and quiz activities within one manipulative medium. Practically, the product offers teachers a structured way to transform abstract processes into visible and participatory learning experiences. The findings contribute preliminary evidence that interactive manipulative media can support conceptual understanding, although the small single-school sample limits generalization.

Keywords: Conceptual Understanding, Elementary Science, Interactive Learning Media, Interactive Smart Wheel, Matter State Changes

A. Introduction

Conceptual understanding is a central goal of elementary science education because it enables students to explain phenomena, connect related ideas, and apply knowledge in unfamiliar situations. Students who understand a concept can move beyond recalling terminology. They can describe relationships, provide examples and non-examples, interpret representations, and explain events in their own words. This ability is particularly important at the elementary level because early scientific ideas become the foundation for more complex learning in later grades (Nanda & Rani, 2025; Roy et al., 2025; Waterman et al., 2020).

Matter state changes are among the science topics that frequently create learning difficulties. Melting, freezing, evaporation, condensation, sublimation, and deposition involve processes that cannot be observed fully at the particle level. Students may see ice become water or droplets form on a cold surface, but they may not understand how heat transfer and particle movement explain these changes. Consequently, students often memorize the names of changes without being able to explain causes, sequences, or examples from daily life (He et al., 2025; Machová & Ehler, 2023).

Initial observations in the fourth-grade classroom at SD Swasta IT Zia Salsabila indicated a similar problem. Several students could identify the names of matter state changes but had difficulty explaining the processes in their own words and connecting them to everyday events. The classroom teacher also reported that students needed more concrete and engaging learning support. These findings suggested that the instructional problem was not merely a lack of factual knowledge, but a gap between remembering terms and constructing meaningful conceptual relationships (Roelle & Richter, 2026).

Interactive Smart Wheel media was selected to address this gap. In this study, the media refers to a physical rotating wheel divided into eight sections. Six sections represent different matter state changes through pictures and QR-linked videos, one section contains a quiz, and one section provides an integrated review of the topic. Students rotate the wheel, observe a visual representation, access the related explanation, discuss the phenomenon, answer questions, and present their reasoning. The sequence combines physical manipulation, visual information, digital content, and verbal explanation in a single activity (Smyrnaiou et al., 2020).

The design is grounded in three complementary perspectives. First, the concrete-operational perspective suggests that elementary students learn more effectively when abstract ideas are represented through visible objects and direct actions. This principle informed the use of a physical wheel, familiar examples, clear images, and observable learning steps. Second, the cognitive understanding perspective emphasizes interpreting, classifying, comparing, explaining, and applying information. These abilities guided the quiz items, discussion prompts, and concept-understanding test. Third, constructivism views learning as an active process in which students build meaning through interaction, prior experience, discussion, and reflection. The wheel therefore does not function only as a display; it prompts students to predict, discuss, justify, and revise their explanations (Kudina et al., 2025).

The integrated design also provides a clear mechanism for supporting conceptual understanding. The rotating action attracts attention and selects a learning task. Pictures reduce the distance between scientific terminology and observable events. QR-linked videos show processes that static illustrations cannot represent adequately. Group discussion allows students to test their explanations against the ideas of peers. Quiz and presentation activities require students to retrieve, organize, and communicate concepts. Together, these components are expected to shift learning from passive reception toward active conceptual construction (Scheiner et al., 2026).

Previous studies of spinning-wheel and smart-wheel media have generally reported positive responses, improved engagement, or better learning outcomes. However, many products emphasize game elements or final achievement scores without clearly integrating physical manipulation, process visualization, conceptual questioning, expert validation, user practicality, and pretest-posttest evaluation within one development cycle (Haryadi et al., 2026). The present study addresses this gap by developing a topic-specific Interactive Smart Wheel that combines a physical wheel with QR-supported video explanations and structured concept questions, and by evaluating the product through the complete ADDIE process.

The study contributes a practical prototype for elementary science instruction and a development framework that links design features directly to conceptual-learning processes. Rather than treating attractiveness as the primary criterion, the product was designed to support students in identifying, interpreting, comparing, explaining, and applying matter state-change concepts. The study therefore examines not only whether students enjoy the media, but also whether the media is valid, practical, and associated with improved conceptual understanding (Dafouz & López-Serrano, 2026). This study addresses the research questions: 1) How can Interactive Smart Wheel media be developed through the ADDIE model to enhance fourth-grade students' conceptual understanding of matter state changes? 2) What is the validity of the developed media based on media-expert and material-expert assessments? 3) What are the practicality and effectiveness of the media based on teacher and student responses and the improvement in concept-understanding test scores?

B. Methods

This study used Research and Development to produce and evaluate Interactive Smart Wheel learning media (Setiyawan & Syamsuddin Nurul Iman, 2026). The ADDIE model was selected because it organizes development into five connected stages: analysis, design, development, implementation, and evaluation. The study was designed as a local product-development trial rather than a large-scale experiment. Accordingly, the findings describe the feasibility and preliminary effectiveness of the product in one classroom context.

The research was conducted at SD Swasta IT Zia Salsabila, a private integrated Islamic elementary school. The participants were 25 fourth-grade students from one intact class, one fourth-grade classroom teacher, one media expert, and one science-material expert. The available research documentation did not record the students' age range, gender distribution, prior achievement profile, the teacher's years of experience, or detailed academic biographies of the validators. These characteristics were therefore not included as analytic variables, and the results are interpreted cautiously as evidence from a single local development trial (Li et al., 2026).

At the analysis stage, the researcher observed science instruction, interviewed the classroom teacher, reviewed the learning needs, and identified students' difficulties in explaining matter state changes. The analysis focused on the gap between students' ability to name a change and their ability to explain its process and application. The results were translated into product requirements: concrete presentation, clear visuals, active student participation, process explanations, short assessment tasks, and compatibility with classroom use (Du et al., 2020; Hontvedt et al., 2023).

At the design stage, the researcher planned the wheel structure, learning sequence, visual content, QR-linked materials, quiz activities, usage guide, expert-validation instruments, practicality questionnaires, and concept-understanding test. The wheel was divided into eight sections (Breuer et al., 2021). Six sections presented the principal changes in the state of matter, one section contained a quiz, and one section provided an integrated review. Images and color distinctions were used to help students identify each section, while QR codes provided access to short process-oriented videos.

At the development stage, the planned design was produced as a physical Interactive Smart Wheel (Creaser et al., 2023). The initial version was reviewed by a media expert and a material expert. Media validation focused on visual organization, readability, technical function, attractiveness, safety, ease of operation, and consistency of the wheel components. Material validation focused on scientific accuracy, suitability for the fourth-grade level, clarity of examples, alignment with learning objectives, and the relevance of questions. Suggestions from the validators were used to revise the product before implementation.

At the implementation stage, the revised media was used in fourth-grade science learning. Students rotated the wheel, observed the selected image, accessed the QR-linked material, discussed the phenomenon, answered the related question, and presented their understanding. The classroom teacher supported the learning process, while the researcher observed student participation and practical difficulties (Juuti et al., 2021). A pretest was administered before the learning activity and a posttest after the use of the media.

At the evaluation stage, evidence from expert validation, teacher and student questionnaires, observation, and pretest-posttest scores was analyzed. Formative evaluation occurred during analysis, design, and development through feedback and product revision. Summative evaluation focused on the final validity, practicality, and improvement in conceptual understanding (Atwa et al., 2024; Buléon et al., 2022).

Data were collected through observation notes, a teacher interview guide, expert-validation sheets, teacher and student response questionnaires, documentation, and a concept-understanding test. The concept test assessed students' ability to identify types of matter state changes, connect changes with daily examples, distinguish related processes, and explain causes or sequences (Garcia I Grau et al., 2021). The available documentation did not report reliability coefficients or inter-rater agreement for the instruments. This limitation is considered when interpreting the findings.

Expert-validation and practicality scores were converted to percentages using $P = (f/n) \times 100\%$, where f is the score obtained and n is the maximum possible score. Concept-test scores were calculated as the score obtained divided by the maximum score and multiplied by 100 (Hsu & Chen, 2025; Korur et al., 2025). Improvement was assessed using normalized gain, $g = (\text{posttest} - \text{pretest})/(\text{maximum score} - \text{pretest})$. The reported N-Gain value represents the mean of students' individual normalized-gain scores.

Table 1. Assessment Scale

Score	Category
4	Excellent
3	Good
2	Fair
1	Poor

Table 2. Validity Interpretation

Percentage	Criterion
81–100%	Highly valid / highly suitable for use
61–80%	Valid / suitable for use
41–60%	Less valid / requires major revision
0–40%	Invalid / unsuitable for use

Table 3. Practicality Interpretation

Percentage	Criterion
81–100%	Very practical
61–80%	Practical
41–60%	Less practical
0–40%	Impractical

Table 4. N-Gain Interpretation

N-Gain (g)	Criterion
g > 0.70	High
0.30 ≤ g ≤ 0.70	Moderate
g < 0.30	Low

C. Results and Discussion

1. Result

Analysis Results

The needs analysis showed that students' conceptual understanding of matter state changes was still limited. Students were generally able to mention several terms, but many had difficulty explaining why a change occurred, distinguishing processes with similar everyday appearances, and relating the concepts to familiar events. The teacher also indicated that existing instruction relied heavily on verbal explanation and required a medium that could provide concrete representations and active participation (Ndabaga et al., 2023; Sterner et al., 2020).

The analysis resulted in six principal product requirements. The medium needed to (1) visualize each matter state change, (2) show processes rather than only final conditions, (3) involve students physically and verbally, (4) provide immediate questions or tasks, (5) be simple enough for classroom operation, and (6) connect science concepts with daily-life examples. These requirements guided the subsequent design.

Design Results

The product was designed as a rotating wheel containing eight learning sections. Six sections represented melting, freezing, evaporation, condensation, sublimation, and deposition. Each section combined an image with a QR code linked to explanatory material. A seventh section contained quiz activities, and an eighth section provided a summary and integrated review. A pointer indicated the selected task when the wheel stopped (Perrier et al., 2023).

The learning sequence was designed so that students did more than spin the wheel. After a section was selected, students observed the representation, accessed the video when appropriate, identified the process, connected it with a real-life example, discussed the cause of the change, and communicated their conclusion. A media-use guide and assessment instruments were prepared at the same stage (Pumptow & Brahm, 2021).

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Figure 1. Initial Interactive Smart Wheel Design

Development Results

The initial design was produced using accessible materials and then submitted for expert review (Elangovan & Sundaravel, 2021). The media expert assessed the appearance, organization, readability, technical operation, and classroom usability. The material expert assessed scientific accuracy, the relevance of examples, alignment with fourth-grade learning objectives, and the clarity of questions. Revisions improved the consistency of the visual symbols, the arrangement of QR codes, the clarity of the selected tasks, and the overall usability of the wheel. The validation scores indicate that the product met the established feasibility threshold (Achuthan et al., 2021; Anjara et al., 2020). The media expert awarded 57 of 60 points, or 95.0%, and the material expert awarded 54 of 60 points, or 90.0%. The mean validation score was 92.5%, which falls within the highly valid category.

	
Figure 2. Product Before Revision	**Figure 3. Product After Revision**

Table 5. Expert Validation Results

No.	Validator	Score Obtained	Maximum Score	Percentage	Classification
1	Media expert	57	60	95.0%	Highly valid
2	Material expert	54	60	90.0%	Highly valid
–	Mean	–	–	92.5%	Highly valid

Implementation Results

The revised media was implemented with 25 fourth-grade students. During the activity, students rotated the wheel, observed the selected representation, accessed QR-linked materials, discussed questions, and presented their answers. Observation showed that the wheel increased visible participation and created opportunities for students to explain concepts rather than only listen to explanations (Nguyen & Tran, 2023; Rizk & Hillier, 2022). At the beginning of implementation, some students required guidance to follow the exploration sequence independently and to move from naming a phenomenon to explaining it. As the activity progressed, students became more familiar with the procedure and more willing to contribute during discussion and presentation. This observation suggests that the medium still requires teacher facilitation, particularly during first use (Sah & Li, 2022).

Evaluation Results

The average pretest score was 42.8, while the average posttest score was 84.8. The mean of the students' individual normalized-gain scores was 0.748, equivalent to 74.8%, and was classified as high. The results indicate a substantial improvement in conceptual-understanding performance after the learning activity. Because the study did not use a comparison group or inferential statistical test, the improvement is interpreted as preliminary evidence rather than definitive proof of causality (Reid et al., 2024; Weidlich et al., 2024). Teacher and student responses also indicated high practicality. The teacher score was 69 of 72 points, or 95.8%. Students obtained a combined score of 2,136 of 2,500 points, or 85.4%. The average practicality percentage was 90.6%, placing the media in the very practical category.

Table 6. Concept-Understanding Test Results

Indicator	Result	Interpretation
Mean pretest score	42.8	Initial conceptual understanding
Mean posttest score	84.8	Conceptual understanding after implementation
Mean N-Gain	0.748 (74.8%)	High improvement

Table 7. Teacher and Student Practicality Responses

Evaluator	Score Obtained	Maximum Score	Percentage	Criterion
Teacher	69	72	95.8%	Very practical
Students	2,136	2,500	85.4%	Very practical
Mean practicality	–	–	90.6%	Very practical

2. Discussion

The findings indicate that the Interactive Smart Wheel was feasible as a locally developed learning medium and was associated with a high improvement in students' concept-understanding scores. The strong expert-validation results suggest that the product's visual organization, technical operation, scientific content, and grade-level suitability were coherent enough for classroom use. The teacher and student responses further show that the media could be operated without complicated procedures and was positively received during implementation (Christopoulos & Sprangers, 2021).

The increase from a mean pretest score of 42.8 to a mean posttest score of 84.8 is educationally meaningful because the assessment focused on more than recalling vocabulary. Students were expected to connect state changes with examples, distinguish processes, and explain causes or sequences (Urhahne & Wijnia, 2023). The high mean N-Gain suggests that the combination of manipulation, visualization, digital explanation, questioning, and discussion helped students reorganize fragmented factual knowledge into more connected conceptual understanding.

The results are consistent with earlier studies of smart-wheel and spinning-wheel media that reported increased engagement, positive learner responses, and improved science learning outcomes. The present development extends those findings by integrating QR-linked process videos and concept-focused questions into the physical wheel. This integration is important for matter state changes because static images alone may show the initial and final conditions but cannot always make the transition process clear. The digital component supported process visualization, while the physical component maintained direct classroom interaction (Mateescu et al., 2021).

The findings also support the concrete-operational rationale used in the design. Fourth-grade students benefited from visible images, familiar examples, and physical action. The wheel converted an abstract topic into a sequence of observable learning tasks. However, concrete representation was not treated as an endpoint. Students were also required to interpret the selected representation, explain it verbally, compare it with other changes, and connect it with daily phenomena. This movement from concrete experience toward verbal and conceptual explanation is central to the educational value of the product (Montesinos et al., 2023).

From a constructivist perspective, the media created conditions for active meaning-making (Barbehön, 2020). Students did not receive identical information in a fixed lecture sequence. The wheel generated a task, students activated prior knowledge, discussed possible explanations, accessed additional representation through the QR code, and communicated a conclusion. Peer discussion exposed students to alternative ideas and allowed inaccurate explanations to be reconsidered. The teacher's role shifted toward guiding observation, asking follow-up questions, and helping students connect experiences with scientific terminology.

The media also aligns with cognitive indicators of understanding. Pictures and examples support identification and classification; the comparison of different wheel sections supports differentiation; videos support interpretation of processes; quizzes prompt application; and presentations require explanation in students' own words. This alignment clarifies why an attractive game element alone is insufficient. The learning benefit depends on how each design component is connected to a specific cognitive activity (Mayer, 2024; Vella-Brodrick & Gilowska, 2022).

Practically, the product can help teachers vary elementary science instruction without replacing direct guidance(Rapanta et al., 2020). It can be used for introductory exploration, group review, formative assessment, or reinforcement. The QR-linked content allows process visualization, while the physical wheel remains usable as a discussion tool. Teachers should introduce the operating sequence clearly, check device and internet access before use, organize students into manageable groups, and prepare alternative offline explanations when digital access is limited.

The media also has limitations. Its content is restricted to matter state changes, and the product was tested with only 25 students from one school. No control group was used, so changes cannot be attributed exclusively to the media. Detailed participant demographics, prior achievement, teacher experience, validator biographies, reliability coefficients, and inter-rater evidence were not available in the research documentation. Student enthusiasm may also have been influenced by the novelty of the activity. These limitations reduce generalizability and require cautious interpretation (Beets et al., 2020).

Future research should test the media with larger and more diverse samples, multiple schools, and comparison groups (Anwyl-Irvine et al., 2020). Studies could examine retention after several weeks, compare physical-only and QR-supported versions, evaluate accessibility for students with different learning needs, and adapt the wheel to other science topics and grade levels. Further instrument validation and detailed reporting of participant and validator characteristics would also strengthen the evidence base.

D. Conclusions

This study developed Interactive Smart Wheel media through the ADDIE model and evaluated its validity, practicality, and preliminary effectiveness in supporting fourth-grade students' conceptual understanding of matter state changes. The product combined a physical rotating wheel, visual representations, QR-linked process videos, quiz activities, and guided discussion. This combination was designed to help students move from naming scientific terms toward interpreting processes, connecting concepts with daily events, and explaining ideas in their own words. Expert evaluation indicated high product validity. The media expert awarded 95.0%, and the material expert awarded 90.0%, producing a mean validation score of 92.5%. Teacher and student responses also indicated very high practicality, with scores of 95.8% and 85.4%, respectively. Students' average concept-understanding score increased from 42.8 on the pretest to 84.8 on the posttest, while the mean individual N-Gain was 0.748, categorized as high. These results suggest that the media is suitable for classroom use and can support more active, visual, and meaningful science learning. The practical implication is that teachers can use the Interactive Smart Wheel as a structured tool for exploration, group discussion, formative assessment, and review. Its effectiveness depends on clear facilitation, purposeful questions, and reliable access to QR-linked content. The study contributes a development example that connects each media feature with a conceptual-learning activity rather than treating the wheel only as an entertaining game. These findings also highlight the importance of combining concrete media, digital resources, and guided interaction in elementary science classrooms. Nevertheless, the findings are limited by the small sample of 25 students, the single-school setting, the absence of a comparison group, the topic-specific product, and incomplete demographic and instrument-quality information. Future studies should involve larger and more diverse samples, experimental or quasi-experimental designs, delayed posttests, additional science topics, and more complete reporting of participants, validators, teachers, and instrument reliability.

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