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IMPLEMENTATION OF BRAILLE-ASSISTED UNO CHEMISTRY CARD MEDIA INTEGRATED WITH TOURISM ETHNOCHEMISTRY DIGITAL CONTENT TO ENHANCE THE SCIENTIFIC LITERACY OF STUDENTS WITH VISUAL IMPAIRMENTS

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ABSTRACT

Quality education must be equally accessible, especially to students with special needs, such as those with visual impairments. This study aims to enhance the scientific literacy skills of students with visual impairments by using Braille-assisted UNO Chemistry Card media integrated with tourism ethnochemistry digital content. The method employed an experimental design, utilizing a quasi-experimental approach. The type of experiment used was the Non-Equivalent Pretest-Posttest One-Group Design. The study population consisted of 15 Grade-XII students with visual impairments at SMALB YPAB Surabaya. The test instrument comprised six questions developed based on scientific literacy competency indicators. The results of the dependent T-test on the differences in scientific literacy abilities of students with visual impairments before and after using the Braille-Assisted UNO chemistry card game integrated with ethnochemical content in elemental chemistry learning for grade XII revealed a significance value of $p < 0.05$, so that H0 is rejected. Thus, the research hypothesis that there is a difference in the scientific literacy skills of students with visual impairments after using the braille-assisted UNO chemical element card game media in chemistry learning for grade XII is accepted. The n-gain score showed an increase in the scientific literacy skills of students with visual impairments by 33% (5 students) in the high category and 67% (10 students) in the medium category. Educational card games with braille letters integrated with ethnochemistry digital content for students with visual impairments are novel contribution of this research.

Keywords: media; braille; game; etnochemistry; literacy

INTRODUCTION

The World Report on Disability highlights that more than one billion people living with some form of disability encounter a variety of barriers, particularly in accessing information and education (Fuentes Anton, 2025; Global Education Monitoring Report, 2024/5, Leadership in Education: Lead for Learning, 2024). Communication technologies in educational settings are urgently needed not only for non-disabled students but also for students with disabilities, including those with visual impairments (students with visual impairments). Visually impaired students face significant challenges that may hinder their access to information and technology (Micklos Lewis & Bodner, 2013). Therefore, digital literacy is essential for students with visual impairments, as it broadens their access to information, education, and social opportunities (Bezerra, 2024).

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The social dimension of community life is closely linked to the education of students with visual impairments, particularly in learning chemical elements (Antunes et al., 2012; Talanquer, 2007). Chemistry plays a pivotal role for students with visual impairments just as it does for their non-disabled peers, albeit requiring different pedagogical approaches (Dwinata et al., 2016; Putera, 2023). Mastery of chemistry can help students with visual impairments develop essential life skills, such as reading chemical labels. By acknowledging the importance of chemistry for students with visual impairments and providing adequate accessibility, schools and educators can support them in achieving their full potential in understanding chemical concepts (Taber, 2013; Putera & Hadi, 2024). Hence, there is a strong need for instructional media that facilitate learning for students with visual impairments, such as game-based chemistry learning media.

The development of learning media that integrate gaming elements represents an innovative solution to improve chemistry instruction in the classroom (Badajos et al., 2023; Yenikalaycl et al., 2019). Games can serve as engaging alternative media for students with visual impairments. The UNO Chemistry Elements Card is a learning medium that merges the concept of the UNO card game with chemical elements, particularly those from the main groups of the periodic table (Putera et al., 2022). The primary aim of this medium is to simplify students' comprehension of groups and periods in chemical elements. To ensure accessibility, this medium must be designed with Braille assistance so that students with visual impairments can actively engage with it (Pahlawaty & Aprilia, 2021). Such an approach fosters inclusive chemistry learning that promotes equity, accessibility, and full participation in the teaching and learning process (Parekh et al., 2021; Assi & Cohen, 2024).

The development of an educational game on the concept of elemental chemistry for visually impaired students is an important innovation in realizing inclusive and quality education, as stated in Sustainable Development Goal (SDG) point 4 on Quality Education (Burmeister et al., 2012). By integrating disability-friendly braille and audio-based technology, students with visual impairments can understand the concept of elemental chemistry in an interactive, fun, and independent manner. This approach not only helps overcome limited access to visual learning resources but also encourages equal opportunities to learn science for all students (Chrin & Nardo, 2025; Li et al., 2022). The development of this educational game contributes to creating an adaptive, inclusive learning environment and supports chemistry learning for people with disabilities. Chemistry learning will become more meaningful and accessible when integrated with ethnochemistry content (Singh & Chibuye, 2016; Zowada et al., 2020).

Ethnochemistry refers to cultural practices within society that bear conceptual relevance to chemistry, portraying the chemical practices of cultural groups in everyday life (Dunlop et al., 2020; Flaherty, 2020). Incorporating local wisdom into chemistry instruction can facilitate learning by connecting chemical concepts with community-based cultural practices (Smithenry, 2010; Sutrisno et al., 2020). These artistic elements may include tourist attractions (such as beaches), culinary (traditional snacks), and the arts (*batik and keris*), which can serve as engaging ethnochemical content. Linking chemistry education to local wisdom in tourism provides tangible examples, especially for students with visual impairments, thereby facilitating their understanding of chemical elements through experiential learning based on cultural tourism (Schnepp & Watson, 2023a).

Furthermore, presenting ethnochemistry content in a digital format plays a crucial role in promoting educational inclusivity, particularly for students with visual impairments (Rüschenpöhler & Markic, 2020; Talanquer, 2025). Digitalised materials can be accessed through assistive technologies such as screen readers, audiobooks, or electronic Braille displays, enabling students to explore the interconnections between local culture and chemical concepts without visual barriers (Ferrell et al., 2022). Digitalization also allows for more interactive presentations through audio, narrative descriptions, or simple simulations that reinforce conceptual understanding (Silvana & Darmawan, 2018; Setiawan et al., 2019). This not only enhances accessibility but also creates opportunities for students with visual impairments to gain equitable, independent, and meaningful learning experiences in understanding culturally embedded scientific knowledge.

Blind students often face learning gaps in understanding chemistry concepts, particularly in abstract materials that rely heavily on visual representations such as the periodic table of elements, atomic structure, and the properties of elements (Bandyopadhyay & Rathod, 2017). Limited access to adaptive and inclusive learning media makes it difficult for them to develop in-depth conceptual understanding. Most available chemistry teaching materials are still dominated by text and images, making them difficult for

the visually impaired to use. This situation creates a learning gap between blind and sighted students, potentially hindering the achievement of basic competencies in science (Chen et al., 2020; Delaney et al., 2021). The development of audio-based and interactive educational games on elemental chemistry concepts is an innovative solution to bridge this gap, while simultaneously increasing motivation and providing an equitable learning experience for blind students (Chehadeh et al., 2025).

The development of ethnochemistry-based educational game media for visually impaired students is a follow-up to previous research that focused on integrating local cultural values into chemistry learning (Taber, 2012). This media was developed to create an inclusive, interactive, and meaningful learning experience by adapting chemistry concepts inspired by local wisdom through a multisensory approach, such as sound, vibration, and descriptive narrative. By utilizing visually impaired-friendly educational game technology, this research aims not only to improve understanding of ethnochemistry concepts but also to strengthen student engagement and motivation to learn through a familiar cultural context. This development supports previous research by expanding the application of ethnochemistry to inclusive education, while also being an innovation in the use of adaptive digital media in science (da Silva Junior et al., 2025).

The low level of scientific literacy among students with visual impairments, particularly in learning chemical elements, requires urgent solutions. Inclusive chemistry instruction that ensures equity, accessibility, and full participation is indispensable (*PISA 2022 Results (Volume I)*, 2023). One viable approach is implementing the Braille-assisted UNO Chemistry Elements Card for students with visual impairments. Furthermore, integrating this instructional medium with tourism ethnochemistry digital content has the potential to enhance their digital literacy (Mardiana et al., 2022). This integrated approach constitutes the fundamental concept, state-of-the-art, and novelty of this study.

The low digital literacy of students with visual impairments, especially in learning chemical elements, must be resolved immediately. Inclusive learning for students with visual impairments in chemistry learning that facilitates equality, accessibility, and full participation is urgently needed. One way that can be done is the development of a Braille-assisted UNO chemical element card game media for students with visual impairments. This game media is then integrated with ethnochemical content of Madura tourism to improve the digital literacy of students with visual impairments on Madura Island. This is the basic concept as a state-of-the-art and novelty in this research. Based on the description mentioned above, the researcher will conduct a study entitled: "Implementation of Braille-assisted UNO Chemistry Card Media Integrated with Tourism Ethnochemistry Digital Content to Improve Science Literacy of Students with visual impairments."

METHODS

The method employed an experimental design, utilizing a quasi-experimental approach. The type of experiment used was the Non-Equivalent Pretest-Posttest One-Group Design. This design was chosen because it allowed researchers to measure changes in the scientific literacy skills of students with visual impairments directly through a comparison of the results before and after using the media.

Table 1 Research Design

Pretest	Treatment	Posttest
O1	Braille-assisted UNO Chemistry Card	O2

The independent variable in this study was the use of Braille-assisted UNO chemistry elements cards integrated with ethnochemistry content, and the dependent variable was the digital literacy skills of students with visual impairments. The study population consisted of 15 Grade XII students with visual impairments at SMA LB YPAB Surabaya. The characteristics of the participants in this study were students with visual impairments (blind) who participated in science/chemistry learning and had the ability to read Braille, so they could use the Braille-assisted UNO Chemistry Card media that was developed. The sampling technique used was purposive sampling, namely the deliberate selection of samples based on certain criteria, such as blind students who actively participated in learning and were able to use Braille media. The sample size was determined based on the number of blind students available at the research location, so that all participants who met the criteria were involved, so that the data obtained could represent the real conditions of learning and allow for optimal evaluation of the media's effectiveness.

This study employed a test instrument to assess improvements in scientific literacy among students with visual impairments in elemental chemistry learning. The test instrument consisted

of six questions structured based on scientific literacy competency indicators, including explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting scientific data and evidence (Cansiz, 2019). Additionally, this study used learning materials comprising a syllabus, lesson plans, and worksheets, incorporating Braille-assisted UNO cards for elementary chemistry integrated with ethnochemistry content. All research instruments and tools were validated by media and materials experts.

This research was conducted through three main stages: planning, implementation, and data analysis. The planning stage included a field study at SMALB (Special Special Needs High School), a study of the concept of elemental chemistry in the ethnochemical content of Madura tourism, an analysis of the needs for the development of Braille-assisted UNO Chemistry Card media, and the preparation of research instruments. The implementation stage included the developing digital ethnochemical media and content, validating tools and instruments, implementing chemistry learning using these media, and collecting and analyzing data through scientific literacy tests and interviews. The final stage involved analyzing the research results and drawing conclusions.

This study employed a one-group pretest-posttest design to examine the differences and improvements in scientific literacy outcomes of students with visual impairments after using the developed media. The dependent t-test was used to compare the pre-test and post-test scores, while the n-gain score test was used to determine improvements in digital literacy skills. Data were analyzed with the help of IBM SPSS Statistics 23 for Windows Software.

The analysis of the science literacy improvement test was carried out by calculating the students' test results and the assessment criteria level using the N-gain score formula:

$$g = \frac{Sf - Si}{100 - Si}$$

Information:
G : Normalized gain
Sf : Post-test scores
Si : Pre-test scores
100: Ideal score

Table 2. N-Gain Score Criteria

Presentation (%)	Criteria
$g \geq 0.7$	High
$0.7 > (g) \geq 0.3$	Medium
$g < 0.3$	Low

RESULTS AND DISCUSSION

The summary of the results of the dependent T-test on the differences in the results of digital literacy skills of students with visual impairments before and after using the braille-assisted UNO chemistry card game integrated with ethnochemical content in elemental chemistry learning for grade XII is presented in Table 3.

Table 3. Summary of the Dependent T-Test of Scientific Literacy of Students with Visual Impairments

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest – Post test	-47.33333	7.32575	1.89150	-51.39020	-43.27647	-25.024	14	.000

Based on the results of the Dependent T test in Table 3, it is observable that the significance value of $p < 0.05$, so H0 is rejected. Thus, the research hypothesis stating that there is a difference in the results of the scientific literacy abilities of students with visual impairments after using braille-assisted UNO chemical element card game media in chemistry learning for grade XII is accepted. The following are the results of the category of increasing scientific literacy of students with visual impairments in terms of the n-gain score category:

Table 4. Results of n-gain scores of students with visual impairments' scientific literacy

Category n-gain	Experiment
High	33
Medium	2
Low	-

The results of the n-gain score in Table 34indicated that there was an increase in the scientific literacy skills of students with visual impairments, with 33% (5 students) in the high category and 67% (10 students) in the medium category.

The findings indicate that the Braille-assisted UNO Chemistry Elements Card is effective in enhancing the scientific literacy of students with visual impairments in learning the subject of chemical elements. This instructional medium has been developed by integrating ethnochemistry concepts, specifically tourism-related content that is linked to the content of chemical elements. Students demonstrate greater ability to comprehend chemical concepts when these are contextualized within content that is familiar and relevant to their daily lives (Lhardy & Reina, 2024). This is demonstrated by the increased imagination of students with visual impairments in understanding chemistry when it is applied to tourism-based contexts (Dewi et al., 2019). This approach offers students a novel opportunity to understand and appreciate the relevance of chemistry in everyday life (Kesner et al., 1997; Kind & Kind, 2011).

The criteria the analysis results show a significant difference between the pretest and posttest scores in digital literacy of blind students after using learning media in the form of Braille-assisted UNO Chemistry of Elements cards integrated with ethnochemistry digital content. The increase in posttest scores indicates that this media is effective in improving students' abilities to access, understand, and use digital information related to local culture-based chemistry concepts (Montejo Bernardo & Fernández González, 2021). The integration of Braille allows accessibility for blind students, while the ethnochemistry digital content provides a relevant and meaningful learning context, thereby strengthening the understanding of science concepts through local wisdom. In addition, interactive game forms such as UNO encourage active and collaborative engagement among students, which has a positive impact on improving their digital literacy and learning independence (Fantin et al., 2016; Horna-Saldaña, Canaleta, Perez Perez, et al., 2025).

Educational game media plays a pivotal role for students with visual impairments as it provides an interactive, enjoyable, and inclusive learning experience (Yulianti & Ekohariadi, 2020). Supported by technologies such as audio features, haptic feedback, and digital Braille features, educational games help students with visual impairments grasp abstract concepts, strengthen concentration, and improve memory and problem-solving skills. Furthermore, educational games can foster learning motivation and self-confidence, as students are not merely passive recipients of information but active participants in the learning process, tailored to their specific needs (Fatimah & Hidayah, 2021). Consequently, such media should not be viewed merely as entertainment but as a strategic pedagogical tool to foster equitable, adaptive, and empowering education.

Analysis of the research results shows that the use of Braille-assisted UNO Chemistry of Elements cards integrated with digital ethnochemistry content successfully improves scientific literacy skills in blind students, especially in the chemistry of elements material. This success is evident in increased student participation during the learning process, their ability to recognize and group chemical elements based on their characteristics, and a deeper understanding of the relationship between chemical concepts and local cultural values (Galizia, 2025). The integration of Braille facilitates independent access to information, while the support of ethnochemistry-based digital content provides a more contextual and engaging learning experience. The UNO Chemistry of Elements card game format creates a fun, competitive, and collaborative learning atmosphere, which also contributes to increasing motivation and learning independence of blind students in understanding science concepts meaningfully.

Digital content and technology integration are of paramount importance for students with visual impairments, as they provide access to a more inclusive, interactive, and adaptive learning environment that caters to their needs (Mardiana et al., 2019). Technologies such as screen readers, audiobooks, voice-based learning applications, and digital Braille devices enable students with visual impairments to access the same information as their sighted peers without visual barriers. Specially designed digital content, such as audio narration, tactile graphics, or voice-based simulations, further aids in understanding abstract concepts that cannot be fully conveyed through verbal explanation alone (Hofstein & Kesner,

2006; Ghai et al., 2022). Beyond enhancing comprehension, the use of technology fosters independence, confidence, and learning motivation among students with visual impairments (Astuti et al., 2023). Thus, integrating digital content and technology into education serves as a strategic pathway to creating equitable, empowering, and sustainable learning experiences.

Digital technologies emerge as innovative instructional media for students with visual impairments because they bridge visual limitations by presenting information through accessible modalities such as audio, digital Braille text, and voice-based simulations (Nurwijayanti Rahma et al., 2020). These innovations not only assist students in understanding abstract concepts through multisensory experiences but also encourage more autonomous, interactive, and equitable learning processes alongside their sighted peers (Ali et al., 2024). With the support of digital technologies, learning materials can be flexibly adapted to individual needs, thereby fostering inclusive education and enabling students with visual impairments to maximize their potential.

The findings on the development of Braille-assisted UNO chemistry element cards integrated with digital ethnochemical content indicate that this media has succeeded in significantly increasing the engagement and understanding of chemical concepts in blind students. Based on the interpretation of the displayed data, there appears to be an increase in the average score of students' scientific literacy skills after using this media, especially in the aspects of conceptual understanding, the application of knowledge in the context of ethnochemistry, and the ability to interpret scientific information independently. Data visualization also indicates that the combination of tactile displays (Braille letters and raised symbols) and digital content support in the form of interactive audio plays an important role in facilitating a more effective multisensory learning process (Devera et al., 2025). In addition, the integrated ethnochemical elements make it easier for students to relate modern chemical concepts to chemical practices in local cultures, thereby making the learning process more contextual and meaningful. These findings confirm that integrating technology, culture, and accessibility can be an innovative strategy to improve the scientific literacy of students with special needs, especially those with visual impairments (Ryu et al., 2021; Ntola et al., 2024).

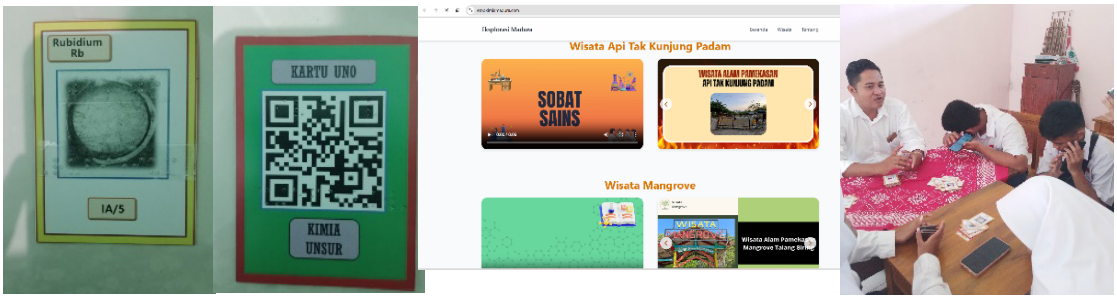

Figure 1. Implementation of Braille-assisted UNO Chemistry Card Media Integrated with Tourism Ethnochemistry Digital Content

Scientific literacy for students with visual impairments in learning chemical elements is highly significant, as it enables them to comprehend fundamental concepts about the properties and roles of elements in daily life, while simultaneously fostering critical and scientific thinking skills (Özkan, 2021). Through scientific literacy, students with visual impairments are not limited to memorizing symbols or names of elements. However, they are also capable of linking such knowledge to real-world phenomena, for instance, the application of metals in technology or the role of gases in sustaining life (Klein et al., 2025). This understanding can be facilitated through adaptive learning media such as tactile models, interactive audio, or inclusively designed educational games. Visual limitations can thereby be minimized, while opportunities to cultivate curiosity, analytical skills, and environmental awareness remain widely open (Pereira et al., 2013; Quattrucci, 2018).

Based on Table 3, the improvement of scientific literacy among students with visual impairments after the implementation of the educational game media remains within the medium category. Although this innovative instructional medium has yielded positive outcomes, further strategies are needed to achieve optimal results. Analysis of the learning outcomes demonstrates that students are already able to grasp basic concepts, interpret simple data, and explain scientific phenomena. However, reinforcement is still necessary in developing critical thinking, evaluating evidence, and applying concepts to broader con-

texts (Subban et al., 2024;Gunawan et al., 2025). Consequently, richer digital content, more interactive adaptive technologies, and intensive guidance through discussion, reflection, and simple scientific investigations contextualized in everyday life are essential (Wedler et al., 2014; Rashid & Chehadeh, 2023). These steps are expected not only to elevate students with visual impairments' scientific literacy from the medium to the high category but also to cultivate independent, applicable, and sustainable scientific reasoning skills.

The indicator of explaining scientific phenomena in scientific literacy for students with visual impairments becomes evident when they can relate the chemical element concepts studied through the Braille-assisted UNO Chemistry Card Game to real-life situations, particularly in the context of tourism ethnochemistry. For example, students may explain the phenomenon of color changes in regional jewelry metals or link the properties of specific chemical elements to traditional materials used in local crafts. The use of this educational game not only facilitates accessible learning through the integration of Braille and digital content but also encourages students to actively reason, engage in discussion, and construct applicable understandings of scientific phenomena (Shen, 2024). This indicator can be optimally achieved when students learn in a contextual, enjoyable, and inclusive manner (Schnepp & Watson, 2023). Such activities help them practice logical reasoning and articulate cause–and–effect relationships in scientific terms using their own language. The combination of tactile media, audio support, and ethnochemical context, makes learning more meaningful (Supalo et al., 2023).

The indicator of evaluating and designing scientific investigations in students with visual impairments' scientific literacy after using the Braille-assisted UNO Chemistry Card Game with digital ethnochemistry tourism content is reflected in their ability to critique, analyze, and construct inquiry steps aligned with real-world phenomena. After playing, students are not only recalling the names and properties of elements but also learning to evaluate the relationship between chemical concepts and environmental events (Schnepp & Watson, 2023c; Haas & Biteen, 2025). For instance, they can assess the validity of the statement that regional silver jewelry tarnishes quickly due to reactions with sulfur compounds in the air. Building on this evaluation, they may design simple investigations, such as identifying independent variables (types of metals), dependent variables (degree of discoloration), and control variables (time and storage conditions). Students can also formulate research procedures that are safe and compatible with their visual limitations, such as using audio guides or tactile models to identify changes (Lee et al., 2024). The integration of Braille media and digital ethnochemistry tourism content makes these activities both accessible and meaningful, enabling students to strengthen critical thinking, design authentic experiments, and connect their findings to sociocultural contexts (Pahlawaty & Aprilia, 2022).

The indicator of interpreting data and scientific evidence in students with visual impairments' scientific literacy after using the Braille-assisted UNO Chemistry Card Game with digital ethnochemistry tourism content can be observed in their ability to process information, identify patterns, and draw conclusions from observations. After engaging with the game, students are not only recognizing element symbols and properties but also learning to interpret data presented in audio narration or Braille text (Parkway et al., 2010). For instance, they may analyze data comparing the rate of discoloration in silver versus copper metals displayed in tourist areas with different humidity levels (Horna-Saldaña, Canaleta, & Perez-Perez, 2025). From such data, they practice interpreting causal relationships, such as understanding that high humidity accelerates oxidation and corrosion. Additionally, they can connect scientific evidence to ethnochemistry in tourism, for example, by linking their analysis to strategies for preserving local metal crafts. This process cultivates analytical reasoning, evidence-based argumentation, and awareness of the application of chemical elements in real life (Arifani et al., 2022). With support for inclusive Braille and digital media, students with visual impairments can interpret data and evidence independently, systematically, and meaningfully (Lees et al., 2020; Putera et al., 2024).

The specific findings on the development of Braille-assisted UNO chemistry element cards integrated with digital ethnochemistry content demonstrate novelty in design, function, and inclusive learning approaches not found in previous research. This product not only adapts a popular educational game into an accessible chemistry learning medium for blind students through the use of Braille and tactile symbols but also integrates interactive digital content featuring audio narration, accompanying visuals, and contextual explanations based on local ethnochemistry (D'Agostino, 2022; Hill, 2025). This integration enables students to understand the concept of ele-

ment chemistry through a meaningful multisensory experience, while fostering an appreciation for local wisdom in traditional chemistry practices. Different from previous research that generally only focuses on tactile print media or separate digital applications, this innovation presents an inclusive hybrid learning model that combines accessibility, culture, and technology aspects in an integrated manner to improve the scientific literacy skills of blind students more comprehensively (Kizilaslan et al., 2019; Lenzer et al., 2025).

Digital content within educational game media plays a vital role in supporting learning for students with visual impairments, as it creates an experience that is more interactive, enjoyable, and accessible through assistive technologies (Satrio, 2019). By incorporating audio elements, haptic feedback, and straightforward narrative instructions, educational games can help students with visual impairments understand learning concepts in a more concrete and applicable manner without relying on vision (Ghai et al., 2022). Furthermore, digital game-based learning fosters independence, enhances learning motivation, and provides a safe exploratory space for students with visual impairments to develop cognitive skills and problem-solving abilities aligned with the subject matter (Ramayanti et al., 2023).

CONCLUSION

The study examined the effect of using the Braille-assisted UNO Chemistry Elements Card integrated with tourism ethnochemistry digital content on the scientific literacy skills of students with visual impairments. The results of the study revealed a significant improvement after the implementation of the Braille-assisted UNO chemistry card game on the scientific literacy skills of students with visual impairments in the subject of element chemistry. The application of this card game resulted in students' scientific literacy skills in the medium category. More importantly, this card game successfully trained five indicators of scientific literacy, consisting of explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting scientific data and evidence. The combination of playing with digital content can train and stimulate the scientific literacy process of students with visual impairments.

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