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Evaluating immersive digital environments through Mayer's principles of multimedia learning

Valutare gli ambienti digitali immersivi mediante i principi della multimedialità di Mayer

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ABSTRACT In recent years, integrating digital technologies in education has fostered the development of immersive and interactive learning environments. This study analyzes digital products made by students in the Technologies of Instruction and Learning course at the University of Turin evaluating them according to Mayer's principles of multimedia. The analysis showed significant results concerning segmentation principles, spatial contiguity, and Interactivity, while personalization and coherence have room for improvement. Results on correlations between variables indicate that appropriate visual and structural design improves the learning experience by reducing redundancy and cognitive overload. The 'balance between multimedia, interactivity, and segmentation is essential to ensure effective learning. The educational implications highlight the need for pedagogic design to maximize the potential of new educational technologies.

KEYWORDS Multimedia; Augmented Learning; Augmented Reality; Gamification; 3D Models.

SOMMARIO Negli ultimi anni, l'integrazione delle tecnologie digitali nella didattica ha favorito lo sviluppo di ambienti di apprendimento immersivi e interattivi. Questo studio analizza i prodotti digitali realizzati dagli studenti del corso di Tecnologie dell'istruzione e dell'apprendimento presso l'Università di Torino valutandoli secondo i principi della multimedialità di Mayer. L'analisi ha evidenziato un ampio rispetto dei principi di segmentazione, contiguità spaziale e interattività, mentre la personalizzazione e la coerenza presentano margini di miglioramento. Le correlazioni tra variabili indicano che un'adeguata progettazione visiva e strutturale migliora l'esperienza didattica, riducendo la ridondanza e il sovraccarico cognitivo. I risultati suggeriscono che un equilibrio tra multimedialità, interattività e segmentazione è essenziale per garantire un apprendimento efficace. Le implicazioni didattiche evidenziano la necessità di una progettazione pedagogicamente solida per massimizzare il potenziale delle nuove tecnologie educative.

PAROLE CHIAVE Multimedialità; Didattica Aumentata; Realtà Aumentata; Gamification; Modelli 3D.

Introduction

In recent years, there has been a significant increase in innovative teaching methodologies, especially in the educational and academic fields. The concept of augmented learning is becoming increasingly prominent, thanks to the possibility of creating highly flexible and adaptable digital learning environments. These methodologies are not new, and technological advances have made educational solutions more flexible and accessible, enabling the development of personalized and inclusive learning paths for students at all levels (Bonaiuti, 2017; Bruschi, 2021). Among the emerging technologies that are changing the educational landscape, augmented reality and 3D objects have attracted some interest. Among the emerging technologies transforming the educational landscape, augmented reality and 3D objects play a leading role. The presence of advanced three-dimensional modeling software and the widespread availability of 3D printers has enabled the integration of these tools into teaching and learning processes (Roopa et al.,2021; Qosimov et al., 2022). Interest in such solutions is related to five key factors:

- Content accessibility and usability enable intuitive and barrier-free use of digital materials.
- Integration into learning environments makes these tools easy to incorporate into immersive teaching platforms.
- The visual impact, manipulation, and representation of concepts in three dimensions overcome traditional two-dimensional representation's limitations and foster deeper understanding.
- Engagement and retention of attention and increased student motivation occur through active interaction with digital objects.
- Contextualization of learning, allowing 3D content to be visualized in real environments, placing them in meaningful scenarios rather than abstract contexts.

While physical models are sufficient to support learning (Yammine & Violato, 2016), digital technologies offer deeper exploration.

For example, 3D visualization makes it possible to analyze the internal structure of the human ear, explore complex anatomical details, and, most importantly, simulate scientific phenomena that are difficult to replay in reality.

These developments fit into a broader perspective of inclusive and augmented learning, concepts gaining increasing relevance in contemporary educational research (Familoni & Onyebuchi, 2024).

Integrating 3D objects and immersive methodologies finds significant applications in STEM disciplines (Science, Technology, Engineering, and Mathematics) and medicine (Moro et al., 2021; Yamazaki et al., 2023), where the manipulation of three-dimensional models strengthens theoretical understanding through practical experiences (Hidayat & Wardat, 2024).

The literature highlights several experiences conducted in educational settings from elementary school to university. It emphasizes the potential of these tools to create immersive and engaging learning environments for students (Geana et al., 2024). (Ibáñez, & Delgado-Kloos, 2018; Roffi & Cuomo, 2022). A crucial aspect, however, concerns the pedagogical design of these technologies. While students appreciate using advanced digital tools, integrating various multimedia formats into an immersive environment can be problematic. The increasing diffusion of virtual tours (Özdemir & Dag, 2022), augmented reality, interactive videos, and gamification calls for a critical reflection on the effects of these tools within the framework of New Media Education, mainly because these contents can be accessed on various devices, including mobile devices (Lisana & Suciadi, 2021). As evidenced in their systematic review, Çeken and Taşkın (2022) point out that the majority of existing studies concentrate on the analysis of instructional activities within conventional learning contexts, whereas significantly fewer investigations have explored the potential of virtual or augmented reality, or more broadly, immersive learning environments. Starting from this perspective, the research has explored the following question: What aspects do students focus on when designing an augmented lesson where they must integrate multiple linguistic codes into an immersive environment?

The initial hypothesis is that a digital environment, when paired with a well-structured instructional design, promotes a better balance of media content.

To answer the question, an analysis was conducted on the projects created by students enrolled in the primary education sciences degree program at the University of Turin, using Mayer's principles of multimedia learning (2005) as evaluation criteria, which will be further explored in the following chapters.

2. Augmented reality and 3D object

Today, the adoption of immersive and augmented reality (AR) technologies is radically changing the teaching of disciplines, offering new opportunities to improve student engagement and learning. AR simulations and three-dimensional environments actively help students understand complex concepts, making content more accessible and interactive (Abdinejad et al., 2021; Avci et al., 2019). These technologies help overcome the limitations of traditional teaching, providing students with a more immersive experience that stimulates active learning, fosters greater engagement (Garzón, 2021; Hidayat & Wardat, 2024), and develops creativity (Yousef, 2021).

Numerous studies have highlighted the educational potential of virtual reality in STEM education, demonstrating how interaction with three-dimensional models and dynamic simulations can significantly improve conceptual understanding and the acquisition of practical skills (Pellas et al., 2017). Exploring interactive digital environments, manipulating virtual objects, and participating in simulated experiments enables students to develop an experimental approach and refine their problem-solving skills (Tzima et al., 2019). Research widely documents the effectiveness of immersive technologies in teaching specific disciplines such as chemistry and anatomy, where visualizing molecular structures or anatomical models in 3D improves comprehension and information retention significantly.

Similarly, using augmented reality in scientific education has positively impacted learning abilities, enhancing student-content interaction through more immersive educational experiences. These studies confirm that immersive technologies and augmented reality represent innovative teaching tools capable of enriching STEM and other disciplines while improving the learning experience through increased Interactivity and student engagement (Szymkowiak et al., 2021). However, for these technologies to be truly effective, their integration into teaching must be appropriately structured and based on solid scientific evidence (Haleem et al., 2022).

3. Multimediality

Multimedia, cognitive load management, and gamification are fundamental to designing effective digital learning environments. Integrating text, images, videos, and 3D models allows for a diversified presentation of information, improving comprehension and content retention. When well-designed, multimedia reduces the risk of cognitive overload, promoting more effective information processing by students. Recent studies show that the combined use of videos and augmented reality enhances engagement and knowledge retention compared to traditional text-based methods (Geana et al., 2024; Gómez-Rios et al., 2022). Hattie's (2008) meta-analysis has long confirmed the effectiveness of student-centered teaching methods in learning.

At the same time, content segmentation plays a crucial role in decreasing cognitive load and optimizing learning processes.

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Cognitive load theory suggests that dividing material into smaller modules facilitates information processing, positively affecting comprehension and attention (Sweller, 2010).

Mobile technologies and augmented learning enable more flexible and adaptive access to educational content, reflecting this approach (Criollo- C et al., 2021).

Research highlights that integrating interactive and multimedia methodologies within a structured environment enhances learning effectiveness.

This effect is strongest when educators harmonize visual and textual elements to avoid Redundancy and facilitate a more intuitive experience (Sansone & Ritella, 2020).

Another key element that supports learning is gamification, which applies game mechanics (points, challenges, levels, rewards) to educational contexts.

Recent studies show that gamification boosts student motivation, enhances their learning experience, and encourages active participation (Kao et al., 2023). This approach becomes particularly effective when combined with multimedia elements and segmentation strategies.

It breaks content into interactive and engaging activities, reducing the risk of cognitive overload (Khaldi et al., 2023). Gamification has also proven especially useful in e-learning environments, where integrating game dynamics helps maintain student attention and engagement (Zeybek & Saygı, 2023). In summary, multimedia enhances learning by structuring information clearly and accessibly, balancing different communication formats, and using segmentation strategies to facilitate cognitive processing. Gamification transforms learning into a more dynamic and engaging process, increasing motivation and improving knowledge acquisition.

4. The education field

The Instructional Technologies and Learning course, which is part of the Primary Education Sciences curriculum at the University of Turin, aims primarily to provide second-year students with conceptual and methodological elements related to technologies in the educational field. One of the course's sub-objectives is to train students in designing learning environments and being able to choose the principles and methods for online teaching. In 2024, students created augmented teaching lessons as a requirement for passing the final exam, producing approximately 100 augmented lessons in total. The professor asked students and non-attendees to create a micro-lesson on a specific topic, incorporating multimedia elements such as a 3D object. The work was done individually on a topic chosen and agreed upon with the course instructor. The lesson design followed two phases. First, we ask students to complete the following grid (Table 1).

In the second phase, students were asked to implement the design grid using a free program called Thinglink. This program allows the creation of virtual and digital environments that are not exclusively educational but suitable for such purposes. For assessment, each product could be awarded between zero and five points, which could be added to the final exam score, with a maximum of 26/30 points. Below is the reference table with the evaluation criteria (Table 2).

In the next paragraph, we will analyze the reference sample.

4.1. The sample

One hundred project sheets and 100 digital products created by primary education students were collected. As previously described, the digital products were required to feature:

Table 1. Project grid.

Target	Characteristics of the participants
Aims	The learning goals
Discipline	For example, subjects such as history, science, Italian, and related disciplines.
Topic	For example, Egypt or the Roman Empire
Description of the context	Formal or non-formal context. Is the activity carried out at school or in an extracurricular setting?
Setting	How is the space organized?
Times	What are the design timelines?
Description of the activity:	Describe the multimedia elements that characterize the activity (objects, images, videos, etc.)
Work phases and reference methodologies	In which teaching moment does the activity take place? What methods are employed?
Technologies	App, Software
Expected results	What knowledge or skills are expected to be acquired?

Table 2. Evaluation grid.

Criteria	Description	Score
1. A 3D object (downloadable from Sketchfab.com)	Students were required to identify a 3D model relevant to the lesson content on the Sketchfab platform. The 3D model can be accessed using mobile devices and, in some cases, projected using augmented reality.	1
2. At least one textual description of the content	Students were required to insert one or more textual descriptions related to the theme addressed, coherent with other elements. They were asked not to insert a referential lesson description but to add important content-related information.	0,5
3. At least one image and one explanatory video	Using the ThingLink platform, students are required to select either a 2D or a 360-degree image to begin their work. Subsequently, they were asked to include at least one 2D image or a video as content within their project.	0,5
4. At least one game related to the contents	Students were asked to balance gamification principles learned during the lesson with educational content.	1
5. Educational value, not just entertainment value	This included creating game environments, balancing educational elements with entertainment, and paying attention to cognitive overload. Students were expected to design clear and coherent content aligned with the educational design principles in the project grid.	2

1. A background: a 2D or 360-degree image that had to be consistent with the referenced lesson. The option to choose the background was influenced by the difficulty of finding 360-degree images through search engines (see Fig. 1 and 2).
   As illustrated in Figure 3, 2D images account for a higher proportion (68%) compared to 360-degree images (32%). This distribution aligns with the instructional design objectives, which emphasized the development of an augmented learning activity, with a particular focus on augmented reality. Nevertheless, the inclusion—albeit less frequent—of 360-degree images indicates an exploratory use of more immersive environments, thereby extending the learning experience toward the affordances of virtual reality.

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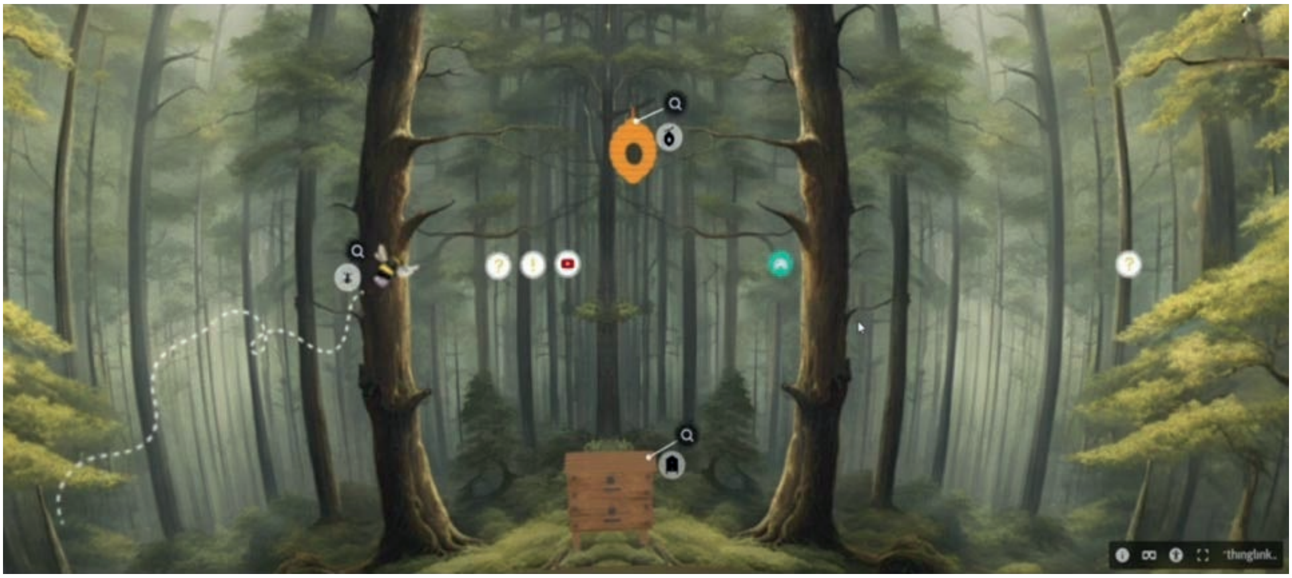

Figure 1. 360-degree Image within the ThingLink environment. Image created by Thinglink's artificial intelligence.

Figure 2. 2D Image within the ThingLink environment created by Canva.

2. A 3D object is consistent with the educational objectives and provides added value to the lesson. In this case, 3D objects were also selected through the Sketchfab website. The 3D objects had to be clear, high-resolution, and relevant to one of the lesson topics (see Figure 4).

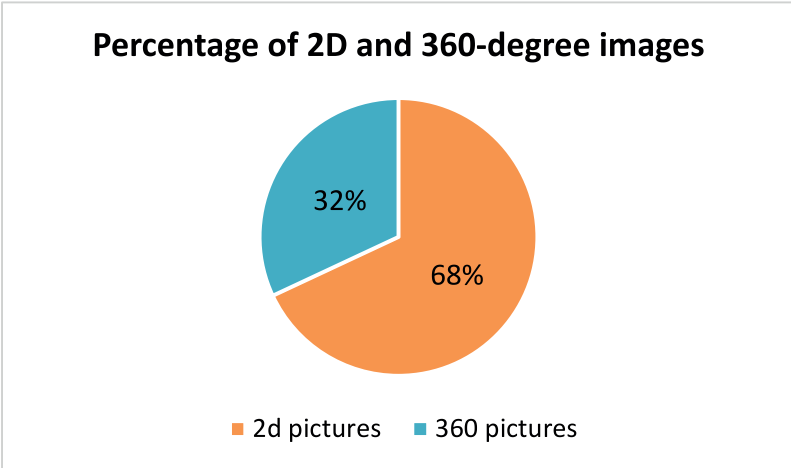

Figure 3. Percentage of 2D and 360 degrees images.

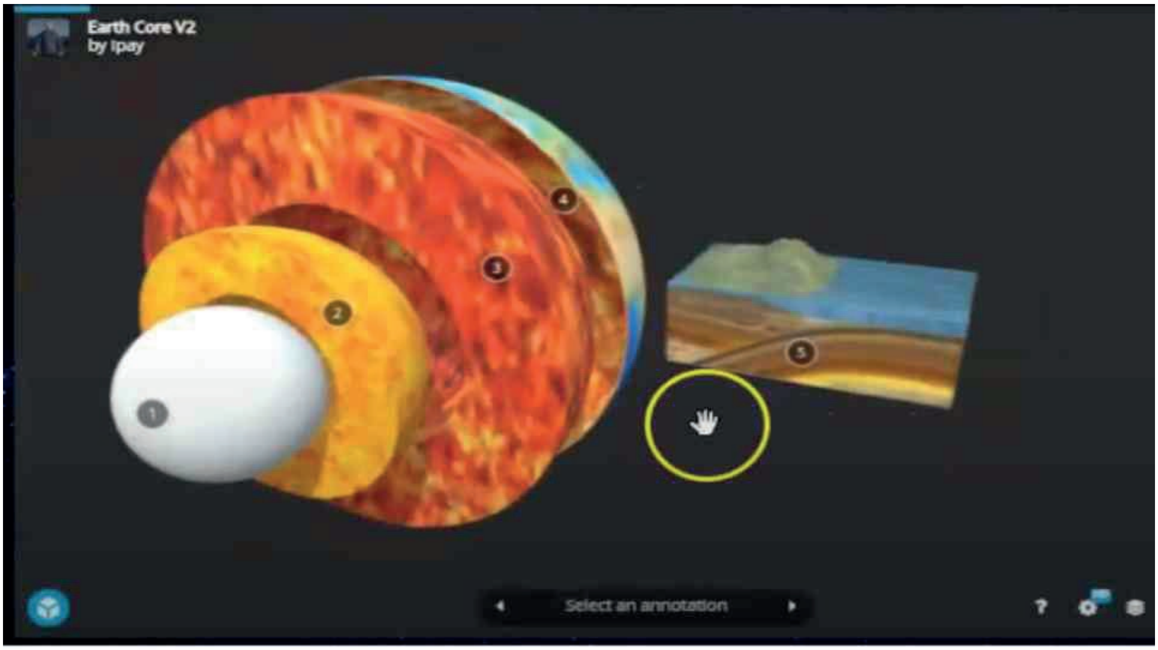

Figure 4. The 3D object of the Earth's layers. Image of Ipay from Sketchfab.

3. Images or explanatory videos of the lesson: Students could create a video or retrieve one from the web.
4. The images could be: a) Referential (representing the described object); b) Evocative (metaphors to enhance the understanding of certain concepts); c) Schematic (visual diagrams to improve comprehension) (See Figure 5).
5. A game: Created using learning apps, serving different functions: a) A game to identify prior knowledge; b) A game to assess acquired skills; c) A game to facilitate learning of educational content.
6. A voice recording of textual parts: To enhance inclusivity.

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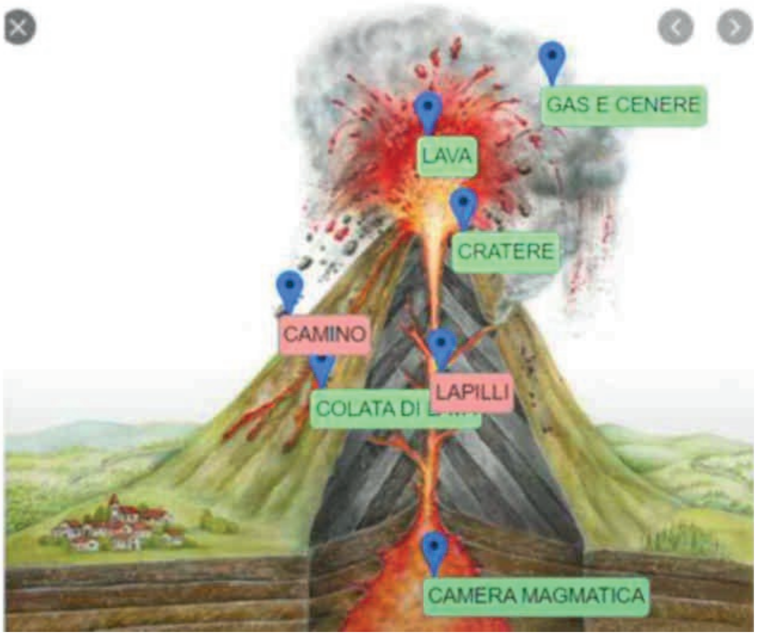

Figure 5. An example of an association game is created by learning apps.

5. Method

The analysis was conducted by applying Mayer's (2005) principles of multimedia learning using a Likert scale with values ranging from 1 to 5. The correspondence of values is shown below:

= Very low: The evaluated aspect is minimally present or almost absent.

= Low: The aspect is present but limited and underdeveloped.

=Middle: The aspect is moderately present but not fully developed or optimized.

= High: The aspect is well integrated into the product and proves effective.

=Very high: The aspect is strongly present and optimized, fully meeting the expected criteria.

A 5-point Likert scale was chosen due to its widespread use in educational research as a reliable instrument for capturing subjective judgments. It enables the identification of nuanced differences in the degree to which each of Mayer's principles is present or effectively applied. The scale offers a suitable balance between ease of use and analytical sensitivity, allowing qualitative observations to be translated into quantitative data while maintaining consistency across evaluative criteria. This approach also supports the application of descriptive and correlational statistical analyses.

Given the exploratory nature of this study, the evaluation of the projects and digital products was carried out by a single expert with extensive knowledge in media and digital communication. To ensure consistency and transparency, the assessment criteria were grounded in established frameworks and supported by current research in the field of multimedia learning.

The evaluation grid was specifically designed for this study, taking into account both Mayer's principles of multimedia learning and the affordances of emerging immersive technologies. Particular attention was devoted to ensuring a balanced integration and interaction of various multimedia modes within contemporary immersive environments, in according with Mayer (2024). This approach allows for a more accurate and relevant assessment. It is sensitive to the complexity and educational potential of advanced immersive technologies.

Table 3 provides an overview of the reference principles, their description, and a concrete example of what should be included in digital products. The Likert scale was applied to each principle.

Table 3. The table contains Mayer's principles, descriptions, indicators, and product evaluation scores.

Principles	Description	Indicators	Score
Multimedia	Use a combination of text, images, videos, and 3D models to facilitate understanding.	A lesson on the circulatory system uses an interactive 3D model of the heart, accompanied by a video or an explanatory image and short texts describing the main parts.	From 1 to 5
Coherence	Avoid unnecessary visual or auditory elements that could distract or overwhelm the student.	Avoid excessive background music or unnecessary animations in educational videos.	From 1 to 5
Segmentation	Divide content into smaller, manageable units with frequent interactions.	Break content into tasks, making use of multimedia.	From 1 to 5
Spatial Contiguity	Present related information close together, avoiding the need for students to search for it in distant areas.	For example, text labels appear directly near structures rather than in a separate window.	From 1 to 5
Modality	Use audio and images to explain complex concepts, avoiding reliance solely on written text.	An image accompanied by a narrated text, which should be concise.	From 1 to 5
Redundancy	Avoid repeating the same information unnecessarily (e.g., saying something aloud while displaying a long-written text that repeats the same content).	For example, a 3D model is accompanied by concise text points but not a long paragraph that duplicates the audio.	From 1 to 5
Personalization	Use natural and engaging language.	First-person narration or interactive questions directed at the audience to increase engagement.	From 1 to 5
Interactivity	Encourage active participation with quizzes, virtual object manipulation, and simulations.	Develop educational and playful games to encourage active participation.	From 1 to 5
Image's first	Favor images over long text explanations to enhance comprehension and reduce cognitive overload.	Instead of a long paragraph describing the water cycle, a diagram with labels and a short explanation is used.	From 1 to 5

The data obtained from the evaluations were subsequently aggregated, and various analyses were conducted, including:

- The frequency distribution of each variable.
- The average values for each variable.
- The analysis of correlations between variables.

6. Results

Starting from the frequency distribution based on the Likert scale, the table below shows relatively regular frequency percentages for all principles, with some differences for certain variables (Figure 6).

By calculating the average scores (see Figure 7), students had to pay the least attention to the following principles:

Personalization (3.26), Image's first (3.57), and Coherence, which received a score of 4.05.

The products exhibit low Redundancy (1. 55), meaning the literal transcription of text-based content into audio or video format is minimal.

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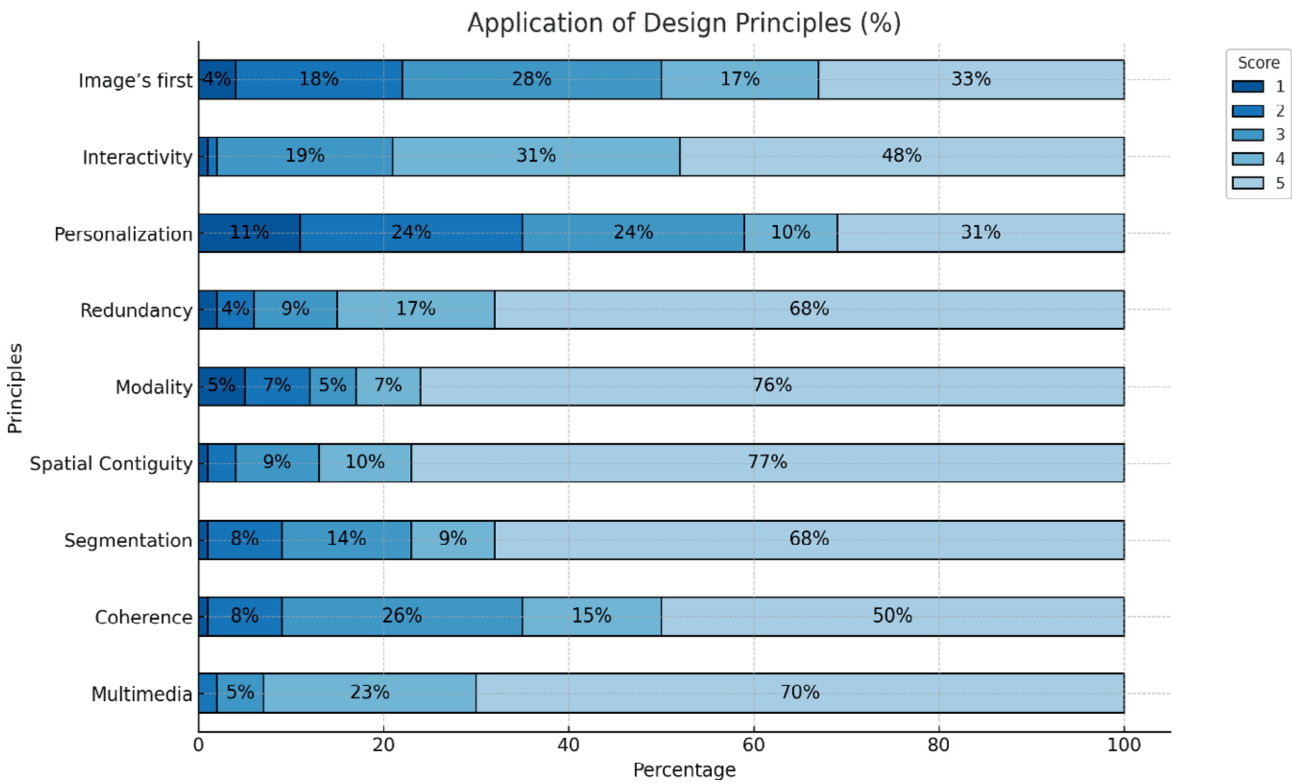

Figure 6. Frequency distribution for each principle.

Multimedia (4.61) and Spatial Contiguity (4.59) have the highest scores, suggesting that most digital products effectively integrate videos, images, and 3D models and that these elements are well-organized within the space.

Segmentation (4.35) and Interactivity (4.24) receive high scores, indicating that many digital products properly divide content into smaller modules and offer interactive activities. This confirms that segmentation is a common strategy for improving usability and engagement.

Coherence (4.05) and Modality (4.42) have slightly lower values, suggesting that some products could still improve in terms of narrative structure and Coherence between elements (text, images, audio).

Personalization (3.26) has a lower average than other indicators, highlighting that many digital products do not offer customization features to meet users' specific needs.

Redundancy (1.55) has the lowest value, indicating that most digital products avoid unnecessary repetitions of information.

The standard deviation does not indicate significant differences. Specifically, we observe that:

Lower standard deviations for multimedia (0.68), Spatial Contiguity (0.85), and Interactivity (0.86) indicate that most digital environments follow similar standards for these criteria.

Modality (1.17), Personalization (1.40), and Images first (1.23) show greater variability, suggesting that some products excel in these aspects while others lack them.

Redundancy (0.95) has a relatively high standard deviation compared to its low average, meaning that some products still include repetitive elements, although most avoid Redundancy.

In the following paragraphs, we present the results obtained for each principle.

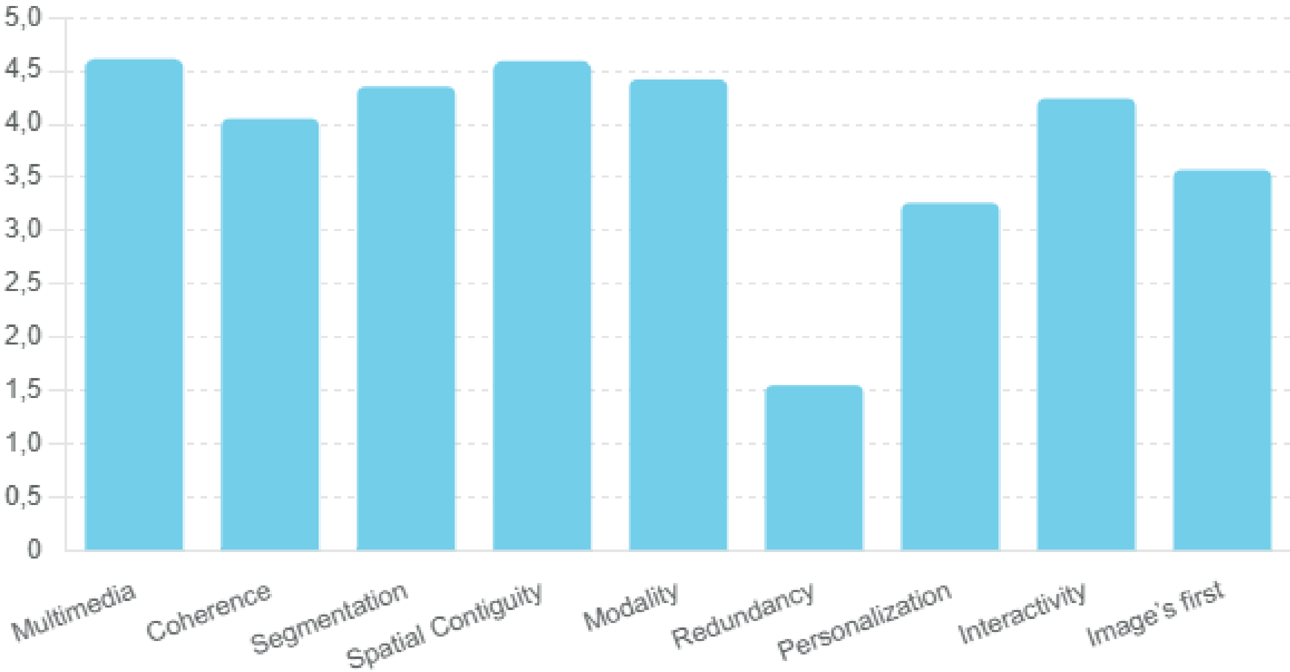

Figure 7. Average values for each variable.

6.1. Multimedia

Most of the analyzed digital products align with the guidelines regarding the multimedia principle.

Specifically, 70% of the products fully met the expected objectives, while an additional 23% showed only minor deficiencies without significantly compromising overall quality.

Conversely, the lowest percentages (5% and 2%) highlight cases where the required multimedia elements were absent, or the project objectives were misaligned with the proposed theme.

In these cases, the selection and integration of multimedia elements within the digital environment were inadequate, compromising the Coherence and overall effectiveness of the product.

6.2. Coherence

Moving on to Coherence, a significant percentage of the products (50% and 15%) adhere to this principle. However, 26% scored a three on the scale, while 8% scored a 2. Coherence was assessed based on various elements. For example, some backgrounds appeared particularly confusing and contained unnecessary elements. See the examples below.

In this Image (Fig. 8) we see numerous padlocks and many poorly connected lines, making it difficult for the user to determine where to start.

Additionally, the number of figures and objects in the background (clouds, white and grey papers, and the lighting effects near the characters in the center of the scene) tend to overlap with the interactive tags (padlocks), text, and lines inserted in the Image, obstructing a clear and linear reading of the picture. The following figure (Fig. 9) shows an image taken from an educational video featuring a distracting element. The video focuses on the anatomical structure of bee legs, associating them with the colloquial term "small tongues". However, when this term is mentioned, an image of a cat with

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Figure 8. Background Thinglink example. Image created by artificial intelligence.

Figure 9. Example of a distracting image (created by Canva).

its tongue sticking out appears, accompanied by a sound effect mimicking the cat's tongue movement. This visual and auditory choice introduces a distraction, as the Image of the cat overlaps with the primary content, fragmenting attention and compromising the understanding of the scientific concept

Figure 10. Pyramid of food. Image of Ewan Sutton from Sketchfab.

being explained. Including unrelated elements in an educational video can reduce its didactic effectiveness, diverting students' focus from the main topic.

The selection of certain 3D objects can also be unclear and potentially distracting, as illustrated in the following example. The Image appears chaotic and blurry, making it difficult to distinguish between the different elements present. This lack of visual clarity can compromise content comprehension and reduce learning effectiveness (Fig. 10).

Distracting music or sounds are less frequent. In two cases, the games featured deafening music with an overly fast-paced rhythm during quiz questions. In this instance, the emphasis was placed more on the playful and educational dimensions. In one case, however, the video was sped up to the point where it prevented the reading of speech bubbles.

6.3. Segmentation

The segmentation principle highlights a relatively high percentage (68%) of selecting specific themes that support effective instructional design. Choosing well-defined topics allowed for more targeted and interactive activities, often integrated with gamification elements, to explore specific aspects of the lesson in a structured way.

However, in a smaller percentage of cases (14%), difficulties were encountered in narrowing down the topic, creating overly broad and unfocused digital products.

In these instances, materials became overloaded with information, covering an entire topic rather than focusing on specific aspects.

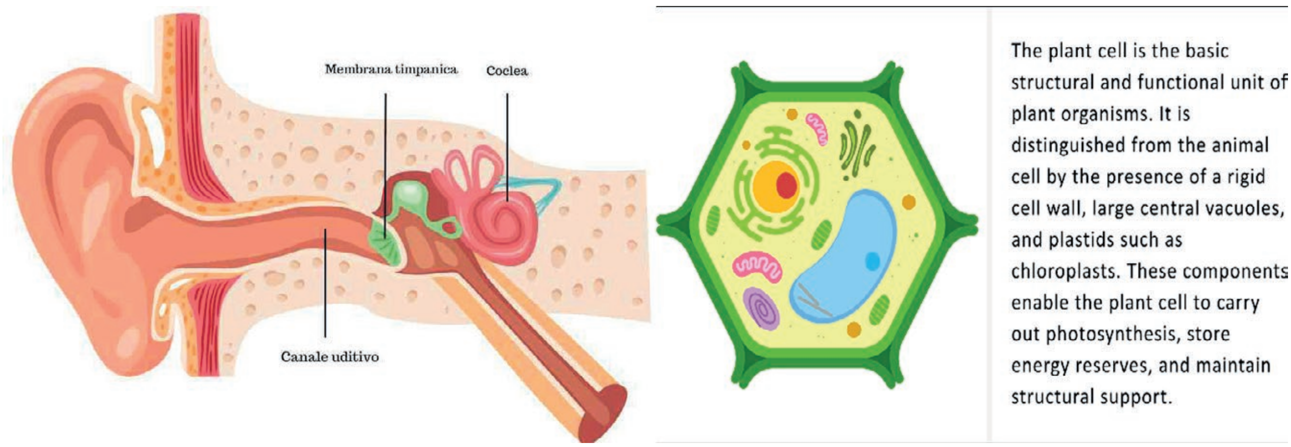

Figure 11. On the left: properly structured image. On the right is an image with adjacent text.

A notable example is slide-based videos, in which numerous aspects of a topic are presented without clear segmentation, making it more difficult for students to process the content effectively.

6.4. Spatial contiguity

Regarding spatial contiguity, most products do not present significant issues. Numerous activities include schematic illustrations annotated with labels that specify particular content, as seen in the image on the left (Fig. 11). In contrast, others present an image accompanied by a textual explanation, as shown in the image on the right in Figure 8.

6.5. Modality

Regarding Modality, the educational lessons generally featured a well-balanced presence of images and text (76%). However, in some cases, no narration accompanying the written text was present (7% scored 2; 5% scored 1). Therefore, most products use verbal and auditory channels to respect this principle.

6.6. Redundancy

Multiple communication and expression channels were often employed to explore specific concepts in greater depth. 68% of the products adhere to this criterion, while only a small percentage (between 2% and 4%) shows low compliance. Conversely, for score 3 (9%), the products contained some redundant elements but were still functional overall.

6.7. Personalization

Personalization is a particularly problematic aspect. The analysis of textual and oral communication methods reveals a heterogeneous distribution in the use of engaging and adaptive language.

31.1% of digital products use natural and engaging language. In these cases, guide characters and storytelling are widely used to support and direct the learning journey. The language is predominantly in first person, and the selected characters are consistent with the topic, fostering a more immersive and interactive experience.

24% of the products, scoring intermediate (value 3), use formal yet somewhat engaging language, especially in videos. Narrative guide characters are also present in these cases, though with less direct interaction. The language in this category oscillates between formalism and direct interaction, often characterized by explicit questions addressed to the audience, both in textual and oral forms.

35% of digital products (24% scored 2, 11% scored 1) lack communicative engagement. The formal and didactic learning environments present essential information without interactive elements. In these cases, stimulus questions are not used to engage the audience, and the language is detached, with content that may appear disjointed and static.

6.8. Interactivity

Gamification is one of the most frequently used methods to enhance Interactivity within digital environments. It is important to recall that students must include this type of activity. Therefore, an evaluation was conducted to determine whether the created games were merely digital replicas of traditional tasks (such as a classic evaluation quiz) or if they introduced innovative interactive elements.

Indeed, 48% of the games, including crosswords, horse races, name-image associations, and puzzle completions, served as problem-solving functions.

31% met the assignment requirements but mainly consisted of fact-based games, which were visually and aurally appealing but lacked deeper engagement beyond aesthetics.

3% created educational games, but these were not very playful, focusing more on text-based content.

Examples include excessively long fill-in-the-blank texts or text-based association games overloaded with visual and textual stimuli, lacking proper segmentation.

See the example below. Special attention was given to the target audience (Figure 12).

Figure 12. Image-text association game for a second-grade primary class.

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6.9. Image's first

Regarding the Image's first principle, the analysis of digital products reveals a varied distribution of implementations of this criterion. A significant percentage of the products fully adhered to this principle (33% scored 5, 17% scored 4), demonstrating an effective use of images to support text and enhance content comprehension. However, a smaller proportion of products only partially integrated this aspect, where images were present but not constantly optimized regarding placement and relevance to the textual content (28% scored 3).

Finally, a minority of digital products exhibited more noticeable issues, with image placement not conducive to learning or an overreliance on text, which could compromise readability and visual impact (18% scored 2, 4% scored 1). This aspect suggests the need for greater attention to visual design to ensure an effective balance between text and images, thereby improving the user experience.

6.10. Coherence of the 3D object

Finally, the presence of a 3D object as an added value to the design was also analyzed. It was observed that the 3D object was coherent with the project and, more importantly, provided an educational benefit rather than merely being a visually appealing addition. 74% of the products exhibited these characteristics, while 26% presented some issues. One of the most common problems was choosing a topic, which inevitably influenced the selection of the 3D object.

In some cases, students selected images that did not provide clarification or additional information relevant to the topic.

In Figure 10, we present an example of the same topic addressed similarly but with two different 3D objects. Both cases explain the cycle of water. However, the first example depicts the snowflake in a recognizable and stylized form without further explanation. Moreover, the accompanying verbal and textual narrative remains at a superficial level, describing the transformation of water without providing detailed information on the differences between the molecular structure of snowflakes and that of water after the transformation. In contrast, the second figure (Fig. 13) highlights a more specific aspect: the ice molecule. Although the 3D object on the right does not convey additional information on its own, it is integrated into the chemistry-related activity, aiming to support the understanding of the chemical process underlying the transformation of water.

6.11. Results of correlation analyses

This paragraph presents the results of the correlation analysis between variables. Figure 14 displays the values obtained by calculating the Pearson correlation coefficient, which was used to identify significant associations between the examined variables. This methodology was applied to determine whether specific variables increase or decrease together. For instance, the analysis allows us to verify whether there is a relationship between content segmentation and Redundancy or whether the level of Personalization is correlated with an increase in the use of a specific presentation mode.

We observe several significant positive and negative correlations reported in Table 6, which will be discussed in the next paragraph.

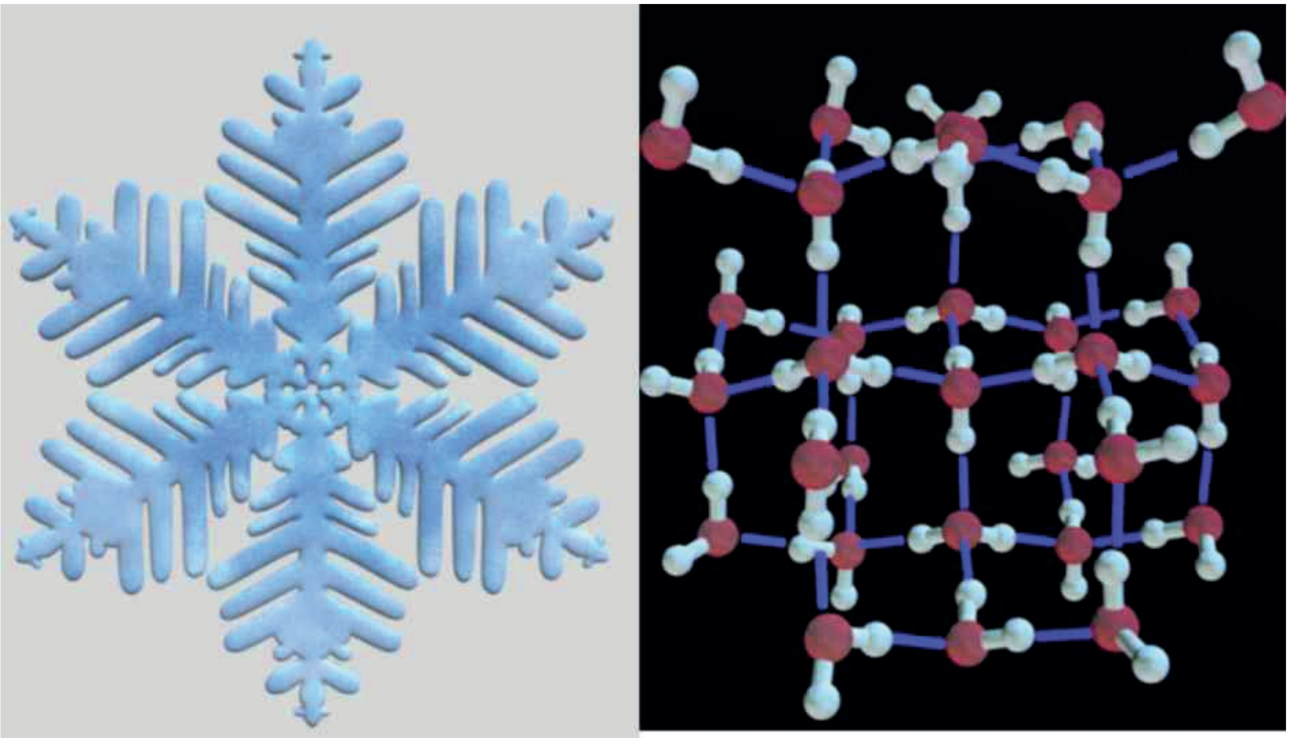

Figure 13. On the left: snowflake. On the right: ice molecule. Both pictures were taken from Sketchfab: Snowflakes (Created by Toonz Media Group); ice molecule (created by Clauter).

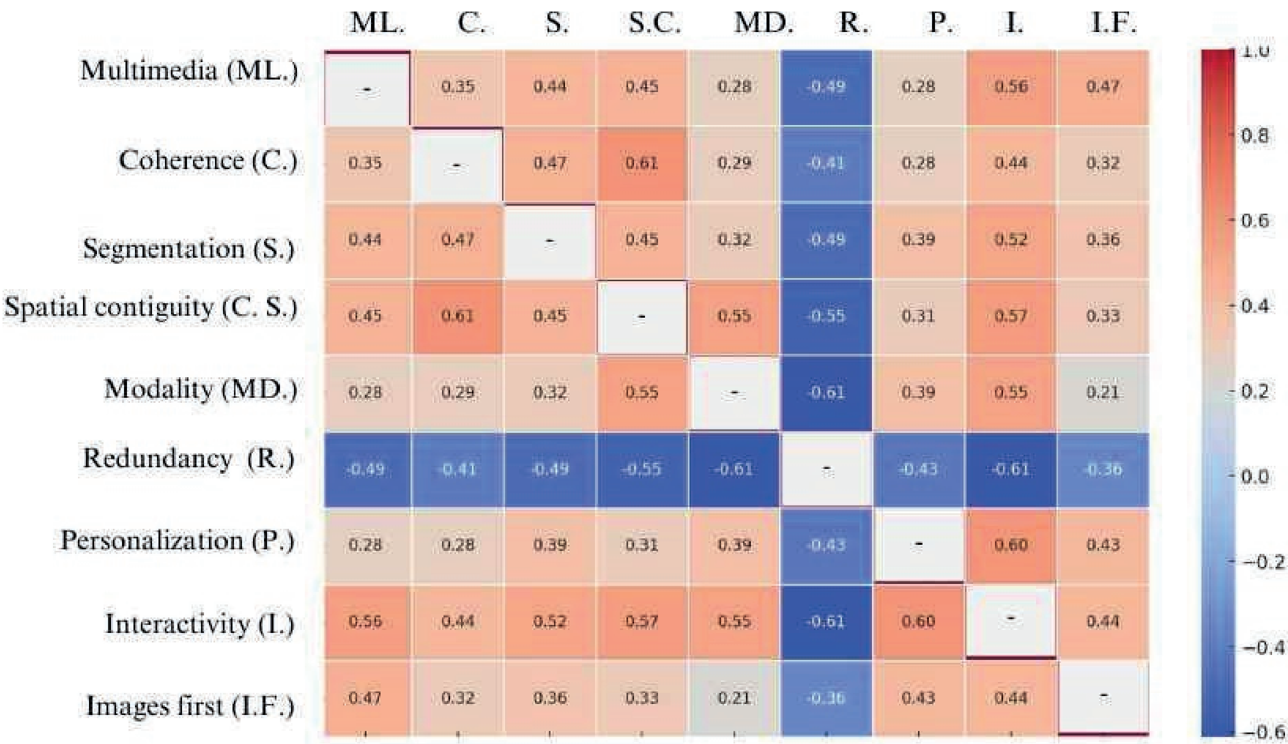

Figure 14. Analysis of correlations between variables.

Table 6. Positive, moderate, and negative correlations.

	M. & I.	I. & S.	I. & S.C.	C. & S.C.
Positive correlations	0.52	0.55	0.57	0.61
	M. & S.C.	**I.F. & M.**	**P. & I.**	
Moderate correlation	0.45	0.47	0.60	
	R. & I.	**R. & S.C.**	**R. & M. (voiceover)**	
Negative correlations	-0.61	-0.55	-0.61	

7. Discussion

The analysis of the digital products created shows that, in most cases, they adhere to multimedia principles, ensuring the effective use of multiple communication codes. However, some aspects exhibit greater variability, particularly in Coherence, Personalization, and Multimedia. One particularly interesting element is the use of first-person narration through guide characters, which has proven effective in enhancing Interactivity and facilitating a better selection of images and visual content. Additionally, integrating 3D objects within digital products has been consistent with instructional design, providing a more inclusive learning channel.

Multimedia elements have enhanced content accessibility, with only a few cases where 3D objects were out of context or educationally inadequate. The correlation analysis between design variables has revealed significant connections, suggesting important implications for designing immersive digital environments.

The strong correlation between Coherence and Spatial Contiguity (+0.61) suggests that well-structured content, free from unnecessary or distracting elements, favors an effective arrangement of text and images within digital spaces. This correlation improves overall accessibility, ensuring a clear and structured user experience.

Similarly, the positive relationship between Interactivity and Spatial Contiguity (+0.57) indicates that highly interactive learning environments featuring well-structured games tend to organize images, texts, and activities more effectively.

This aspect implies that the design of interactive experiences must consider two key aspects: a) The structure of the environment, which must include clear rules and a logical arrangement of content. b) Game design, where images, texts, and interactive dynamics must be harmonized to ensure a smooth and coherent experience.

Another significant correlation is between Interactivity and Segmentation (+0.52), indicating that dividing content into smaller modules facilitates the creation of more targeted activities, reduces cognitive overload, and improves learning experiences. Structuring educational materials into smaller units also allows for the design of more accessible games, limiting content redundancy and optimizing the informational load for students.

Not surprisingly, the positive correlation between Multimedia and Interactivity 0.55) suggests that integrating videos, images, and 3D models is key to creating more engaging interactive experiences. These findings highlight the importance of designing immersive environments with well-organized and visually aligned elements. A structured design not only facilitates Interactivity but also supports segmentation, helping to maintain high student engagement. A well-planned visual and interactive content design promotes more effective and stimulating learning.

On the other hand, negative correlations offer further insights:

The inverse relationship between Redundancy and audio Modality (-0.61) indicates that when audio narration is effective, repeating the same information across multiple formats (text, images, audio) can become redundant.

Similarly, the negative correlation between Redundancy and Spatial Contiguity (-0.55) suggests that well-organized visual content reduces excessive repetition, as clarity is ensured through the optimal arrangement of text and images.

Another interesting finding is the negative correlation between Redundancy and Interactivity (-0.61), showing that higher levels of Interactivity reduce the need for repetition. This point implies that interactive activities should be designed to promote active learning and avoid unnecessary content duplication.

Other moderate correlations suggest that:

Multimedia and Spatial Contiguity (+0.45) are closely linked: the effectiveness of multimedia elements depends on how well they are organized. Harmonizing text and images is essential for immediate and intuitive understanding.

Personalization and Interactivity (+0.60) indicate a more natural and engaging communication style enhances content and activity interactivity. The use of narrative guide characters and first-person narration allows for the creation of more personalized and structured games aligned with the narrative framework.

Images' first and Multimedia (+0.47) suggest that a preference for multimedia content correlates with using images and diagrams rather than long blocks of text. This correlation confirms the importance of visual design in optimizing learning processes.

8. Conclusions

The results of this study highlight the importance of instructional design that balances multimedia, interactivity, and content segmentation. Creating effective immersive digital environments requires a structured and coherent design that promotes clarity and navigability while avoiding information overload and excessive stimuli.

The study aimed to provide an exploratory view of the key elements to be considered in the design of augmented educational activities for future teachers, emphasizing how students tend to devote particular attention to the development of such digital artefacts.

For instance, the use of narrative and interactive tools—such as guide characters—emerged as a key factor in enhancing personalization within digital products. Similarly, content segmentation and the effective management of redundancy are fundamental strategies for reducing cognitive load and improving access to information.

Based on these findings, future research should further investigate the role of interactivity and personalization in learning processes and explore innovative strategies for more effective integration of multimedia content. Moreover, the evaluation grid and the proposed methodology may serve as an initial version of a broader assessment tool to be employed in future studies for comparing multimedia environments from different contexts, with particular attention to increasingly immersive settings.

Additionally, upcoming research could analyze how different configurations of content and interactive tools influence student engagement and performance, thereby contributing to the development of more accessible, inclusive, and effective learning environments.

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