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Article

Augmented Reality for Multilingual Learning in Higher Education

Lucía Amorós-Poveda [1,2,*], Olesea Caftanatov [3] and Joan Antoni Pomata-García [2]

[1] Faculty of Education, University of Murcia, 30100 Murcia, Spain
[2] Faculty of Education and Humanities, International University of La Rioja, 26006 Logroño, Spain; joanantoni.pomata@unir.net
[3] Vladimir Andrunachievici Institute of Mathematics and Computer Science Vladimir Andrunachievici, Moldova State University, MD-2009 Chișinău, Moldova; olesea.caftanatov@math.md
* Correspondence: lamoros@um.es

Abstract

This study utilises mobile augmented reality (AR) to enhance our understanding of multiword expressions (MWEs) and emphasise that linguistic diversity is part of cultural heritage. The main objective was to implement and evaluate the impact of a multilingual AR resource (in Moldovan, English, Russian, and Spanish) in educational settings and to identify a corpus of MWEs located in Spain. The research was conducted by applying a marker-based AR system in five academic subjects involving $N = 220$ undergraduate students enrolled in education degrees. Data were collected through two surveys, using both qualitative and quantitative methods that combined descriptive statistics with content analysis. Large Language Models (LLMs) were used to assist with data coding, complemented by iterative human validation. The findings revealed that the application was highly positively received, with 94% of participants acknowledging its usefulness and 83% expressing satisfaction. Furthermore, this study identified a teaching–learning procedure to enhance linguistic diversity in classrooms. Overall, the results suggest that mobile AR constitutes an effective and inclusive pedagogical tool that fosters active learning as a multimodal learning process and provides valuable localised MWE data to support future developments in corpus annotation.

Keywords: educational technology; information processing; digital transformation; linguistic diversity; multilingualism

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1. Introduction

In a global context characterised by the growing expansion of bilingual and multilingual speakers (Ismailova et al. 2023; Jayanath 2020), the integration of advanced technologies such as augmented reality (AR) has become a crucial area of research to promote linguistic diversity and educational inclusion. AR can be defined as the real-time integration of digital and physical information through various technological devices (Cabero and Barroso 2016). As a technology itself, AR superimposes images, 3D models, or other computer-generated content onto a real image displayed on a screen, allowing users to interact with virtual information while maintaining direct engagement with the physical environment (Prendes 2015). This process enriches a user's perception of reality (Parmaxi

et al. 2024) by offering an immersive experience with tangible applications in real-world scenarios (Titchiev et al. 2023). Overall, AR combines physical and virtual worlds, with the particularity that the real environment is presented with an expanded context (Castellanos and Pérez 2017). AR falls under the broader umbrella of Extended Reality, commonly referred to as Mixed Reality (Rauschnabel et al. 2022) and the metaverse (Cesmeli 2023; Chaljub-Hasbún et al. 2024).

Research into the use of AR (Cabero and Barroso 2016; Cabero-Almenara et al. 2022) is increasingly common in higher education, particularly mobile AR (Barba et al. 2015; Putra et al. 2021. Evidence demonstrates that AR enriches the learning experiences and is effective for improving language skills—such as speaking, listening, reading, writing, and cultural awareness—while offering benefits related to vocabulary, grammar, and pronunciation. It also increases motivation, engagement, and enjoyment while helping reduce anxiety and boost learner confidence (Parmaxi et al. 2024). Applications such as QuiverVision and HP Reveal have been evaluated positively in formative contexts due to their interactivity and educational potential (Cabero-Almenara et al. 2021; Padilla et al. 2019).

In this sense, linguistic diversity further enriches the educational environment. Multilingualism confers significant psycholinguistic and cognitive benefits (see Table 1), including the development of executive function, mental flexibility, and metalinguistic awareness (Calzati and De Kerckhove 2024; Jayanath 2020).

Table 1. Cognitive benefits of multilingualism, adapted from research of Calzati and De Kerckhove (2024, pp. 65–66) and Jayanath (2020, pp. 83–85).

Advantages	What Is the Benefit?	What Is It Developed for?
Executive function	High-level cognitive processes domain	Problem-solving, mental flexibility, attentional and inhibitory control, and task switching
Metalinguistic ability	Understanding the separation between language structure and meaning	Judging whether a meaningless sentence is grammatically correct
Parallel activation	Semantic and phonological activation of both languages during language use	Language activation: continuous, unconscious, and interfering between languages
Semantic development	Preferences of word category	Earlier semantic development
Reading ability	Reading competence and comprehension	Strengthened spoken–written language connection, earlier understanding, and earlier meaning
Thinking flexibility	Cause–effect determinism: refraction	Thinking formalisation: No systematic and causal analysis

It is widely established that digital learning materials support multilingualism and cross-cultural awareness by promoting indigenous literacy. This is implemented through local resources and enhanced literacy development (Van 't Hooft and Romero-Contreras 2025). Furthermore, ensuring that neurodivergent people have access to the Knowledge Society is a key element aligned with the principle of equal opportunities (Cabero and Córdoba 2009) and the Universal Design for Learning (UDL) framework (Alba 2019), which advocates for a more inclusive digital future (Klatte et al. 2024). Nevertheless, while there is growing consensus as to the benefits of multilingualism (Ismailova et al. 2023; Jayanath 2020), the acceptance of education in multiple languages varies globally, ranging from complete acceptance to significant controversy (Dewaele 2015; Jayanath 2020). Moreover, divergent hypotheses exist regarding the most effective path to high linguistic proficiency: early exposure to a foreign language is not the only factor; variables such as the intensity and quality of the input and the ability to use the language in authentic interactions also have a significant impact (Dewaele 2015).

Within this framework, this study focuses on multiword expressions (MWEs), defined as formulaic sequences. An example is idioms (Keck and Kim 2014). The exploration

of idiosyncratic linguistic variations, such as idioms and proverbs (Zaicovskaya 1998), illustrates how cultural and linguistic differences can foster inclusion in the classroom. Ensuring linguistic diversity necessitates the preservation of languages as part of our shared cultural heritage (Beirak 2025). However, not all languages are equally represented in the communication of language technologies (Joshi et al. 2020; Quesada 2025). At this juncture, Suzuki and Storch (2020) posit that significant collaborative endeavours, such as dialogue and interaction, writing tasks, and collaborative scaffolding, must be conducted in accordance with Vygotsky's concept of the Zone of Proximal Development (ZPD). Co-creating language technologies through community agencies must be considered (Quesada 2025). As Natural Language Processing (NLP) advances, it both benefits users and challenges us to preserve and promote linguistic diversity (Savary et al. 2025).

This study is grounded in educational augmented reality (AR) frameworks that integrate variation theory and active engagement to support the development of knowledge, skills, and attitudes (Cabero et al. 2019; Ling Lo 2012; Mazur 2024). AR pedagogy is further underpinned by constructivist, situated, inductive, and game-based learning approaches (Cabero et al. 2019). Within the multilingual learning framework, it is positioned as a key determinant of social inclusion, employability, personal fulfilment, sustainable lifestyles, and active citizenship (Council of the European Union 2018; European Commission 2025). Early language learning is strongly recommended in high-quality early childhood education. As such, multilingualism is a pedagogical resource that fosters language awareness, academic achievement, and social cohesion (Council of the European Union 2019a, 2019b). Linguistic proficiency is assessed through the Common European Framework of Reference for Languages, which emphasises action-oriented, plurilingual, and intercultural education (Council of Europe 2020; CEFR 2023).

However, the adoption of AR faces persistent challenges, including teacher resistance, technical tracking failures, and student distraction. Additionally, high development costs, substantial hardware requirements, and health concerns, such as eye strain, continue to limit its implementation (Schorr et al. 2024). Furthermore, unresolved issues related to AR and linguistic diversity persist, particularly due to the reliance on devices for sign language use (Anil et al. 2025). In addition, it is pertinent to ask how the application of mobile AR contributes to the comprehension of multiword expressions in a higher education context that integrates multiple languages. It is also necessary to examine how contextual factors, such as the multilingual profiles of students and degree programmes, influence the use of AR-based digital tools during teacher education. To address these challenges, the following questions guide this research:

Question 1. What is the impact perceived by students regarding the clarity, didactic quality, and pedagogical usefulness of AR for learning idiomatic expressions?

Question 2. What characteristics define the corpus of MWEs identified in the local territory as action-oriented?

Question 3. How are these linguistic units categorised according to their figurative or literal meaning?

This research addresses technical barriers by evaluating a multilingual AR tool for idiomatic expressions. Findings show high satisfaction, reinterpreting identified distractions as positive engagement and filling the gap in plurilingual education through a new and inclusive localised teaching method following a pedagogical procedure.

As such, the general objective (GO) of this study is to explore the innovative application of mobile AR as a tool to enhance our understanding of MWEs in the Moldovan, English, Russian, and Spanish languages in educational contexts. The three specific objectives are (SO1) to use a digital AR tool with multilingual features in educator initial training, taking into account contextual factors; (SO2) to evaluate the impact of AR resource on

MWEs; and (SO3) to formulate a corpus of MWEs organised into proverbs, idioms, and linguistic peculiarities, located in the Region of Murcia (Spain).

The conclusions highlight the positive feedback from students, the value of an integrated experience, the promotion of diversity and cognitive benefits, and the demand for usability and scalability. Users demonstrated an exceptionally positive perception of the application's quality and utility, confirming its potential as an accessible and effective educational tool (Cabero and Barroso 2016). In this regard, participants strongly appreciated the integrated AR experience, valuing the digital application and its tangible flashcards, thereby reinforcing the relevance of combining physical interaction with digital enhancement to promote motivation and active learning (Cabero-Almenara et al. 2021; Castellanos and Pérez 2017). This study underscores the role of multilingualism and linguistic idiosyncrasies in enriching dimensions of educational diversity and fostering cognitive flexibility and intercultural understanding (Calzati and De Kerckhove 2024; Jayanath 2020). Finally, constructive feedback was gathered focusing on improving usability, interactivity, and accessibility, alongside a strong interest in expanding AR applications to other disciplines such as mathematics, the sciences, and history (Cabero-Almenara et al. 2022; Parmaxi et al. 2024).

2. Context, Materials, and Methods

This is an exploratory, inductive, and descriptive study framed within a qualitative paradigm. A convergent mixed-methods design is employed, assigning equal weight to both quantitative and qualitative data, which were collected and analysed concurrently to obtain complementary and integrated findings (Creswell and Plano Clark 2007). Following Hernández-Leo et al. (2014), this collection of information was combined with the analysis at the beginning of the process, resulting in a number of documents (33 annexes in the form of memoranda and reports). This process was systematically applied across five bachelor's degrees in education, encompassing higher education programmes. In this context, the research focuses on the systematic application and testing of an AR resource using a marker-based augmented system. Training and testing actions (seven sessions, with a total duration of 445 min) were conducted in five classrooms across two locations: Espinardo Campus and the ISEN University Centre. Both are affiliated with the Faculty of Education at the University of Murcia. The overall implementation process involved a total population of 220 undergraduate students ($N = 220$).

The AR resource was integrated into the following distinct programmes: Double Degree in Primary Education and Physical Activity and Sport Sciences (PS), Primary Education—Bilingual Group (PB), Double Degree in Early Childhood Education and Primary Education (CP), Pedagogy Degree (PE), and Primary Education with Therapeutic Pedagogy Mention (PT). The application was implemented across four academic subjects.

A mixed-methods design combined quantitative and qualitative analyses focusing on usability, pedagogical value, and intercultural reflection. Two surveys were used for the assessment. Firstly, the analysis of the AR FlashCards Questionnaire was based on $n = 69$ responses from participants who provided their consent. Secondly, the Idiosyncrasies Survey had a sample size of $n = 86$ for descriptive variables (Section 2) and $n = 54$ for the complex variable dimensions (Section 3).

Validity was ensured through established analytical dimensions (Martínez Sánchez et al. 2002; Walsh et al. 2018). Reliability was addressed via iterative prompting, and a systematic comparison was made between automated outputs and manual coding, with documented discrepancies leading to the exclusion of unreliable artificial intelligence (AI)-generated results. Traceability was maintained through pseudonymisation and detailed prompt and output logs (Annexes 7–14, 28–29 in the BA). The analytical sequence integrated prior manual analysis ("small-scale treatment") to guide and constrain AI-

assisted processing, ensuring consistency with the original qualitative framework and preserving interpretative depth.

2.1. AR Flashcards Questionnaire (RA+)

The AR+ comprises eleven items (Appendix A.1, Table A1) and is categorised by qualitative and independent variables (Kaur 2013; Ochoa and Molina 2018; Pal et al. 2024). The analysis of user perception regarding the AR application was conducted using the AR+, available at https://lc.cx/iPTJi2 (accessed on 31 October 2025). This survey design is structurally based on the five dimensions from Martínez Sánchez et al. (2002). The classification stage involved reducing raw data into homogeneous groups (Dibekulu 2020) and sorting responses into four evaluation dimensions using coding: Identification and Description, Didactic, Psycho-pedagogical, and Global Valuation (Appendix A.2, Figure A1).

The AR+ employs a mixed nominal and ordinal scale, utilising closed, open, and mixed formats. The adoption of this hybrid survey format is linked to its ability to facilitate a deeper understanding of user preferences, support resource personalisation, and strengthen the relationship with the student (Calle et al. 2024, pp. 25–26).

For analysis, closed items relied on descriptive statistics to summarise the data. Consistent with the exploratory nature of this study, no generalisations were made about the population, in line with the non-inferential approach (Dibekulu 2020, p. 11). Data processing began with Google Forms for initial field editing, followed by central editing stages (Kothari 2004; Pal et al. 2024, pp. 478–80). Anonymisation was ensured through pseudonymisation, adhering to the Personal Data Protection Commission Singapore guidelines (PDPC 2022).

The tools employed (Figure 1) for descriptive statistics and content analysis included Excel workbooks and CSV matrices for absolute and percentage values. Data visualisation utilised bar charts and pie charts to present data in a logical and accessible format.

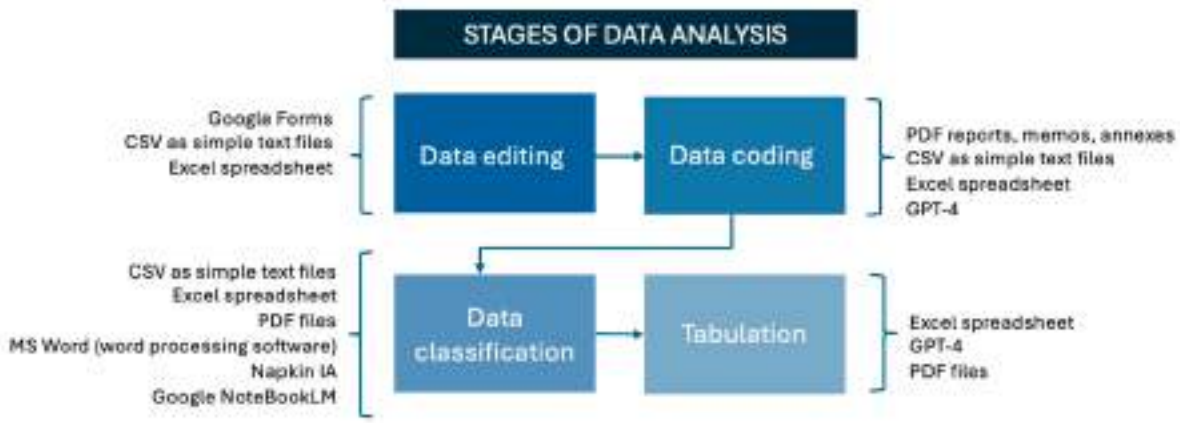


Figure 1. AR+ data analysis tools.

Except for item 1, each question was analysed as an independent entity; PDF reports for each item proved particularly useful. Technological assistance was integral to the data processing. Large Language Models (LLMs) were employed to support deductive coding of qualitative data (Chew et al. 2023; Xiao et al. 2023). Specifically, GPT-4 categorised open responses, supporting the assertion that LLMs can enhance the rigour of qualitative analysis (Goyanes et al. 2025). NoteBookLM was also employed for generating abstracts (González Calatayud 2024, pp. 48–49). This process relied on an iterative prompting system (Gao et al. 2021, pp. 1568–70; Goyanes et al. 2025; Naveed et al. 2024 combined with human review to eliminate inaccuracies or hallucinated responses generated by the GenAI (Burger et al. 2023).

2.2. Idiosyncrasy Survey (IdSurvey)

The IdSurvey (https://lc.cx/DjqPnK, accessed on 31 October 2025), presented in English and Spanish, is designed to catalogue unique linguistic variations in Spanish language varieties. It is divided into three sections, comprising sixteen distinct blocks, based on Zaicovskaya (1998, pp. 235–37). Five blocks address descriptive variables, while eleven blocks correspond to complex variable dimensions (Appendix B.1, Table A2). The structures are available in Appendix A.2, Figure A1. These complex dimensions (e.g., Intellect) encompass 65 attributes. Each attribute requires two responses (an associated comparison word and a related idiom or proverb), resulting in 135 items and a total of 7020 possible responses.

The survey primarily utilises a nominal scale and features qualitative and independent variables, consistent with methodologies described by Kaur (2013), Ochoa and Molina (2018), and Pal et al. (2024). This hybrid design facilitates a detailed understanding of linguistic preferences, supports the personalisation of resources, and strengthens the student–educator relationship (Calle et al. 2024, pp. 25–26).

Given its exploratory nature, the analysis relies on descriptive statistics without making inferences about the wider population (Dibekulu 2020, p. 11). The procedure for data analysis and processing followed similar stages established by both the RA+ and ethical protocols. The tools employed in the analysis (descriptive statistics and content analysis) comprised Excel workbooks and CSV matrices for absolute and percentage values (Figure 2). Data visualisation utilised bar charts and pie charts to present data.

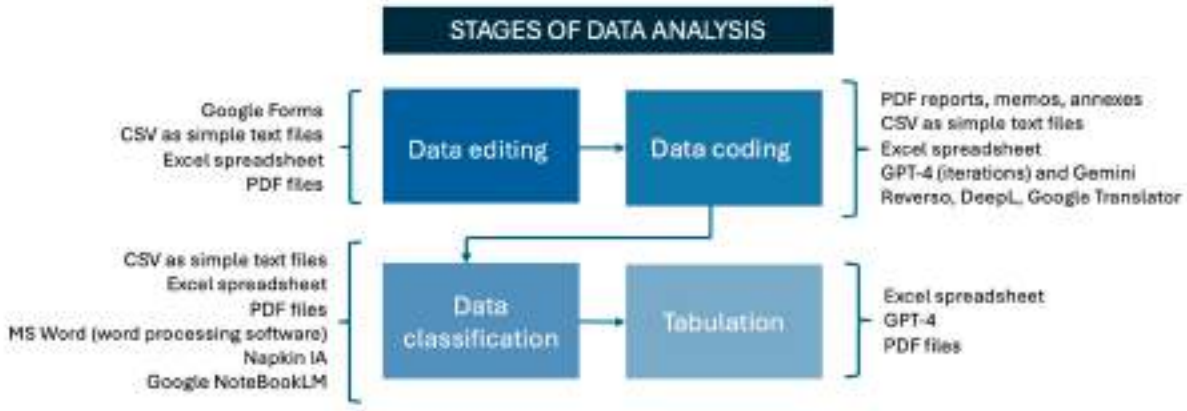


Figure 2. IdSurvey data analysis tools.

The classification stage involved reducing raw data into homogeneous groups (Dibekulu 2020), utilising five groups based on Walsh et al. (2018) for the classification of MWEs (Figure 3), i.e., Category 1. Figurative comparisons were also classified (similes or idioms), e.g., "*blanco como la nieve*"/*white as snow*, "*blanco como el papel*"/*white as paper*, "*parecerse a alguien en el blanco de los ojos*"/*to look like someone else in the whites of one's eyes*.

The examples outlined below are all culturally accepted, figurative fixed comparisons. Category 2 contains specific idiomatic metaphors, e.g., "*ir de punta en blanco*"/*to go toe to toe*, which conveys a figurative meaning that cannot be directly deduced from the literal meaning of the words, unlike those in Category 5. Category 3 includes expressions of obviousness or cultural irony, e.g., "*blanco y en botella*"/*white and in a bottle*, "*¿de qué color es el caballo blanco de Santiago?*"/*What colour is Santiago's white horse?* These expressions use irony to highlight something that is self-evident. Category 4 refers to proverbial expressions or popular sayings, e.g., "*a buen hambre no hay pan blanco*"/*there's no white bread for a hungry man*. Expressions in this category typically convey a moral or popular cultural wisdom. Finally, Category 5 contains metaphors related to literal meaning, such as "*dar en el*

blanco"/*to hit the target*. Like Category 2, this type of expression has a figurative meaning; however, this meaning extends beyond the literal one, incorporating metaphorical or connotative nuances.

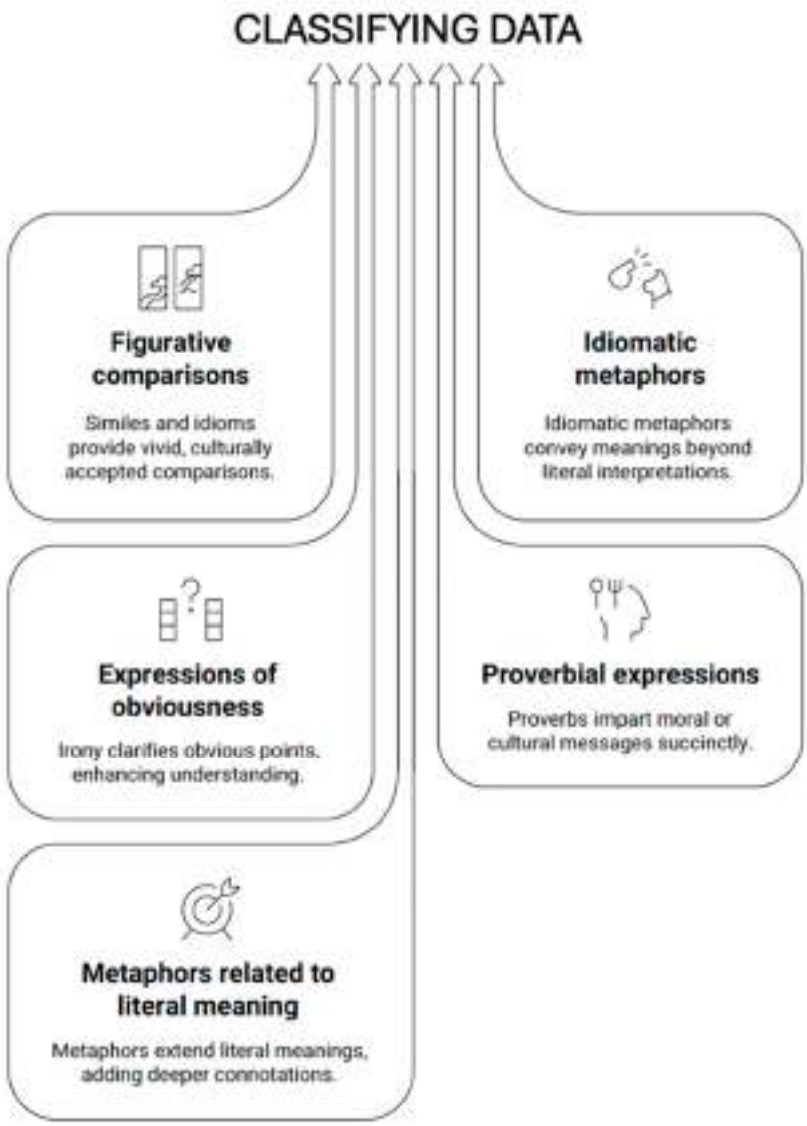


Figure 3. IdSurvey. Classifying data into categories (Walsh et al. 2018).

Crucially, LLMs were integral to deductive coding and sustaining the arguments developed in the AR+. Due to linguistic complexity, including the use of metaphors and proverbs, various translation tools, such as Reverso, Google Translate and DeepL, were required to ensure meaning was contextualised and maintained. Data tabulation was conducted using Excel dynamic tables, leveraging features such as structured referencing, as noted by Shimul (2024). Simple static and dynamic input–output models were also applied based on the Leontief equation (Großmann and Hohmann 2019) for impact comparison. Given the nuances captured, the analysis required both a small-scale treatment (manual, in-depth examination of specific attributes) and a large-scale treatment for full corpus analysis.

The small-scale treatment addressed two dimensions (Colours and Physical Aspects) and eight manually analysed attributes. This manual analysis was conducted using the file *Survey CODE.xlsx*. and used two LLMs (Gemini 2.0 and ChatGPT-4) with human review. Of the eight attributes analysed, six belonged to the Colours dimension, and two

belonged to the Physical Aspects dimension. Following the treatment outlined above, two reports were prepared for the attributes "black" and "white", comprising a total of 27 idiomatic sentences (comparisons, idiosyncrasies, proverbs, and/or MWEs).

The large-scale treatment enabled the handling of greater amounts of data in less time. This allowed us to explore the corpus and extract idioms, comparisons, and idiomatic expressions, as well as to identify popular attributes. Knowledge acquired through the small-scale treatment of the database facilitated the identification of inaccuracies when applying LLM analysis. A Spanish template proved useful in identifying unreliability. In this way, the results were obtained through an iterative process. In the analysis performed, 115 columns were used, representing 65 attributes distributed across 11 dimensions. Dynamic tables work best when data are organised into columns with a single header row. The data treatment process was carried out in three steps: (1st) importing CSV data into an Excel workbook; (2nd) transforming the workbook's *Data Analysis* sheet into dynamic tables, resulting in 39 Excel workbooks and 34 tables with charts as conclusive results; and (3rd) visualising data and reducing the data set using the *Zoom* option. The general procedure is explained in the final report. A total of 33 annexes are available in the Book of Annexes (BA), in which Annex 11 presents 58 attributes and 385 MWEs detected, and Annex 12 presents a total of 1005 distinct phrases, including comparisons, idioms, and proverbs. In line with this, GenAI, in conjunction with human review, was used to generate lists of sentences, graphics, and figures and to assist in analysis, data abstraction, interpretation, and section summaries. The iterative procedures and prompts are located in Annexes 8 to 9 and 11 to 16 of the BA.

3. Results

3.1. Exploring a Multilingual AR Application: Understanding MWEs in Higher Education (GO)

The process of integrating AR in the classroom involves identifying the usefulness of AR to each subject, location, and schedule. A detailed description of each AR activity and its duration should be provided to ensure effective planning and implementation.

This process can align learning objectives with the use of technology, promote student engagement, and enable instructors to monitor outcomes according to subject area, time allocation, and classroom context (see Appendix C). The training procedure successfully supports the development of a systematic teaching–learning process and offers a model for integrating AR media into university instruction (Figure 4).

The systematic process shown in Figure 4, outlined as a cyclical teacher–researcher model, aims to provide multimodal digital resources under a peer-based teaching process. It demonstrates flexible planning, teacher-paired training activities that emphasise oral and visual codes, practical use of mobile AR experiences, and iterative assessment utilising AR+ and IdSurvey in seven sessions. This model emphasises reflective practice and the collection of triangulated data among trainers to document learning processes within university environments.

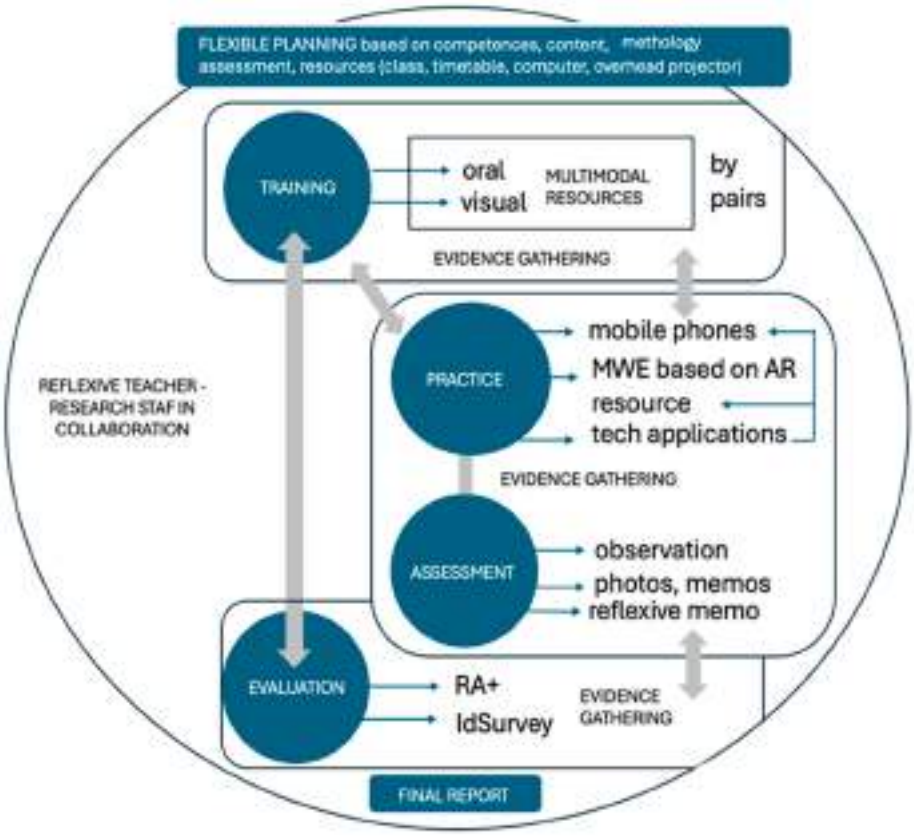


Figure 4. Results from GO. Systematisation of a teaching–learning process using AR for a plurilingual competence in higher education.

3.2. Using a Digital Mobile AR Resource with Multilingual Features in Initial Teacher Education: Considering the Context (SO1)

The data gathered from the AR+ primarily addressed the gender (n = 69), demographics, undergraduate degrees, and location of participants. Data from the IdSurvey, based on 86 responses in Section 2 (Appendix B.2, Figure A2), provided insight into the multilingual profile of the student population.

3.2.1. Participant Demographics and Academic Context

The gender distribution revealed a marked predominance of female students, with 56 females, 11 males, and 2 participants who preferred not to state their gender. This distribution was further detailed across undergraduate degree programmes. The academic context comprised five degrees and four academic subjects. Analysis of degrees by courses indicated that 60% (three degrees) were first-course degrees, while 40% (two degrees) were fourth-course degrees. Considering the number of students who responded, 72% (50 students) were enrolled in first-course degrees, compared with 28% (19 students) in fourth-course degrees. Regarding subjects, 40% (two degrees) were associated with the subject Contemporary educational theory and institutions (CON), while the remaining three subjects—Planning, development and evaluation of teaching (PLA), Management, Leadership, Evaluation and Improvement of Educational Organisation (MAN), and Accessibility and Disability (ACC)—comprised 20% each (one degree each). Student distribution by subject showed that CON-associated degrees accounted for 38% of the respondents (26 students), while PLA-linked degrees accounted for 35% (24 students).

3.2.2. Locations and Distribution of Responses

According to the data collected from the Espinardo Campus and ISEN, which distributed 38 and 31 questionnaires, respectively, the highest number of responses was obtained from students obtaining their CP degree (35% or 24 responses) at ISEN and PB degree (32% or 22 responses) at the Espinardo Campus. Conversely, the PS degree at the Espinardo Campus accounted for only four (6%) of the total responses. Located at ISEN, the PT degree yielded 7 responses (10%), while the PE degree at the Espinardo Campus received 12 responses (17%). These findings suggest that participation levels varied by both location and degree, with *ISEN* demonstrating higher response rates than Espinardo Campus for certain programmes.

3.2.3. Multilingual Profile

The results demonstrated a broad degree of multilingualism, with 44% of the sample speaking two or more languages. Specifically, 56% of respondents (48 students) spoke one language; 29% (25 students) spoke two languages; 12% (10 students) spoke three languages; and 3% (3 students) spoke four languages. The number of different languages spoken within the sample was nine.

Spanish was spoken by 100% of the participants. The next most frequently spoken languages were English, spoken by 26% (22 students), and a combination of Spanish, French, and English, spoken by 10% (9 students). This multilingual profile highlights the relevance of employing a digital AR tool with multilingual features in the context of education. In this sense, the classroom as a multilingual unit can speak Spanish (100%), English (34 students), French (12 students), Arabic (2 students), Portuguese (1 student), Italian (1 student), Korean (1 student), Romanian (1 student), and Catalan (1 student).

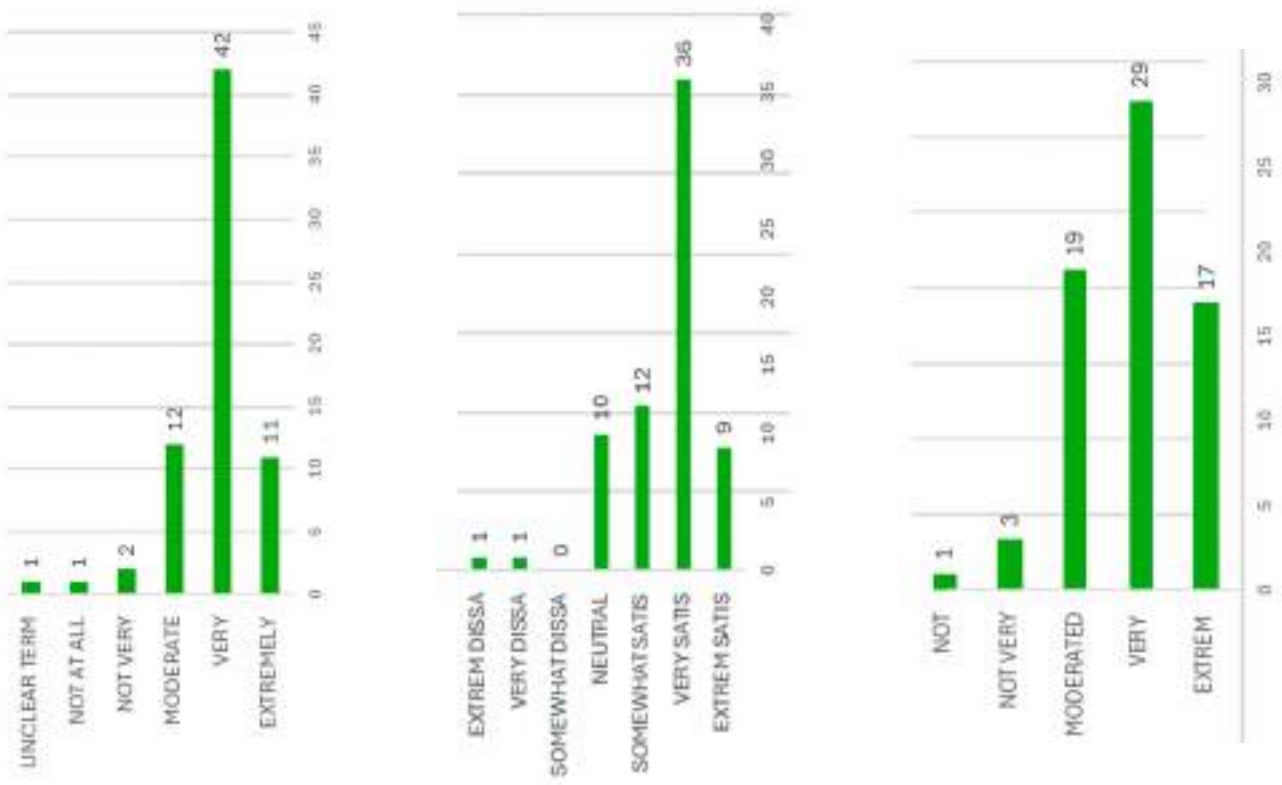
3.3. Impact of the AR Resource Based on MWEs (SO2)

Considering the analysis conducted in SO1 and the ensuing results, the study now focuses on Specific Objective 2 (SO2). To achieve this objective, an examination is conducted of the impact of the AR resource based on MWEs, with a focus on two dimensions: the didactic outcomes from the students' perspective (Section 3.3.1), and the psycho-pedagogical characteristics of the multilingual AR results, as shown in Section 3.3.2.

3.3.1. Didactic Aspects of the Multilingual AR Resource (Clarity, Quality, and Utility)

Participants demonstrated an overwhelmingly positive response to the didactic qualities of the AR material (Figure 5):

1. Clarity. The overall clarity of tasks and scenarios was rated highly, with 94% of users indicating "Yes". The single most frequent rating was "Very clear" (61%, 42 responses). Minimal negative feedback was recorded (6%). Detailed ratings included 17% for "Moderately clear" and 16% for "Extremely clear".
2. Quality (satisfaction). Overall satisfaction was strong, with 83% of responses falling within the "Satisfaction quality" category. The dominant response was "Very satisfied" (52%, 36 participants). Dissatisfaction was exceptionally low (3%, two participants).
3. Utility. Participants showed a near-unanimous agreement (94% "Yes") regarding the educational value of the application. The dominant response was "Very useful" (42%, 29 participants), followed by "Moderately useful" (28%, 19 responses) and "Extremely useful" (25%, 17 responses).



(**a**) (**b**) (**c**)

Figure 5. Results from SO2: (**a**) clarity from unclear content to extremely clear; (**b**) quality from extreme dissatisfaction to extreme satisfaction; and (**c**) utility from not useful to extremely useful.

3.3.2. Psycho-Pedagogical Results (Like, Attention, Dislike, and Suggestions)

Analysis of the data revealed a balanced appreciation for both the app and the physical cards, with 36% and 35% of participants expressing a favourable opinion, respectively. This finding suggests that both the technological and tangible elements were equally valued. Furthermore, digital content proved to be highly engaging, accounting for 73% of the attention factors when combining app content and technical features. While nearly half of the respondents (46%) reported no specific dislikes, some expressed concerns regarding psycho-pedagogical and technical aspects, such as slow performance and compatibility issues. Additionally, the majority of participants (75%) expressed a strong desire to expand the use of AR in academic subjects such as mathematics, science, history, and languages. Suggestions made by participants emphasised the need to enhance interactivity and adapt the material for younger learners, underscoring a pedagogical interest in making this learning experience both accessible and dynamic. In conclusion, these findings confirm the AR resource's high perceived didactic quality and utility, while identifying key areas for refinement related to platform compatibility and interactive enhancements.

1. Liked most (code "Like"): Positive feedback was nearly evenly split between the technological delivery system (code "Application": 36%, 25 students) and the physical learning tool (code "Cards": 35%, 24 students). Content was the third most highly rated aspect (28%). Female respondents, who constituted the majority of the sample, showed the highest preference across these categories.
2. Attention: The variable "App content" was the primary attention driver (43%, 30 responses). When combining the variables "App content" and "Technical App" (30%), digital implementation accounted for 73% of engagement factors.

3. Dislikes (variable "Dislike"): The largest portion of feedback (46%, n = 32) was positive, expressing no specific dislikes (code "Overall assessment") (Table 2). Specific areas of complaint included issues with psycho-pedagogical (17%, e.g., slow performance and difficulty of use) and economic and technical difficulties (16%, e.g., file size and platform compatibility with lack of iOS support).
4. Suggestions for the variable "Lessons" (see Appendix A.2, Figure A1): The dominant interest (75.36%, 52 responses) fell under the dimension "Identification and description", highlighting the desire to apply AR to different subjects.
5. Other suggestions (code "Other", Appendix A.2, Figure A1) were concentrated on psycho-pedagogy (38%), enhancing interactivity and ease of scanning, and didactic aspects (35%). The aim of adapting content specifically for children aged 6 to 12 was recommended.

Table 2. AR+ item "What did you not like about the application?"

Dimension	Focus	n	%
OVERALL	Valuation (opinion, usefulness, recommendations)	32	46
PSYCHOPEDAG	Psycho-pedagogical aspects (motivation, attention, interactivity, learning processes)	12	17
ECONOMY	Economic and technical aspects (cost, storage, technical support, platform compatibility)	11	16
DESCRIPTION	Identification (area, audience, design, content format)	9	13
DIDACTICS	Curriculum (objectives, methodology, content, activities, evaluation, resources)	5	7
	Total	69	100

Recommendations included adapting the application for use in schools (specifically for children aged 6 to 12), splitting complex information into a greater number of cards, creating different types of cards, and suggesting less text for younger students. Economic and distribution aspects (dimension 4, 19%) were specific to technical performance and accessibility. Key feedback concerns included platform availability (making the tool available for iOS and ensuring it is compatible on both Apple and Android devices), reducing file size, and expanding language support (adding more languages). Global valuation suggestions (dimension 5, 8%) addressed general improvements, such as keeping the content up-to-date.

3.4. Identification of a Corpus of Located MWEs (SO3)

To cover as much of the corpus as possible, large-scale treatment was carried out using GPT-4 and Gemini, both of which are available free of charge. Based on prior knowledge obtained from the previous treatment, it was determined that large-scale processing required human review. The small-scale treatment of data yielded ten annexes: six for analysis and two for reports focused on the interpretation of the data, as analysed in Section 3.4.1. Large-scale treatment produced a total of fourteen annexes, three of which were deemed unreliable and one partially unreliable (see Annex 12, pp. 30–31 in the BA). This is discussed in Section 3.4.2.

3.4.1. Small-Scale Treatment and Results

This section explores three key points: the six attributes from the "Colours" dimension (Annexes 18 to 23 of the BA), two attributes from the "Physical" dimension (Annex 26 and Annex 27 of the BA), and idioms from black and white attributes. These were assessed through deep manual analysis (Annex 24 and Annex 25).

Attributes from Dimension "Colours"

For the black category, "*coal/carbón*" was the dominant comparative term (44% of responses), followed by "*charcoal/tizón*" (20%) (Figure 6a). For idioms, the code "*thing/cosa*" was the most frequent (20% responses), often referring to worry or a difficult situation, such as "*La cosa está muy negra*"/*The thing is very black* (Figure 6b).

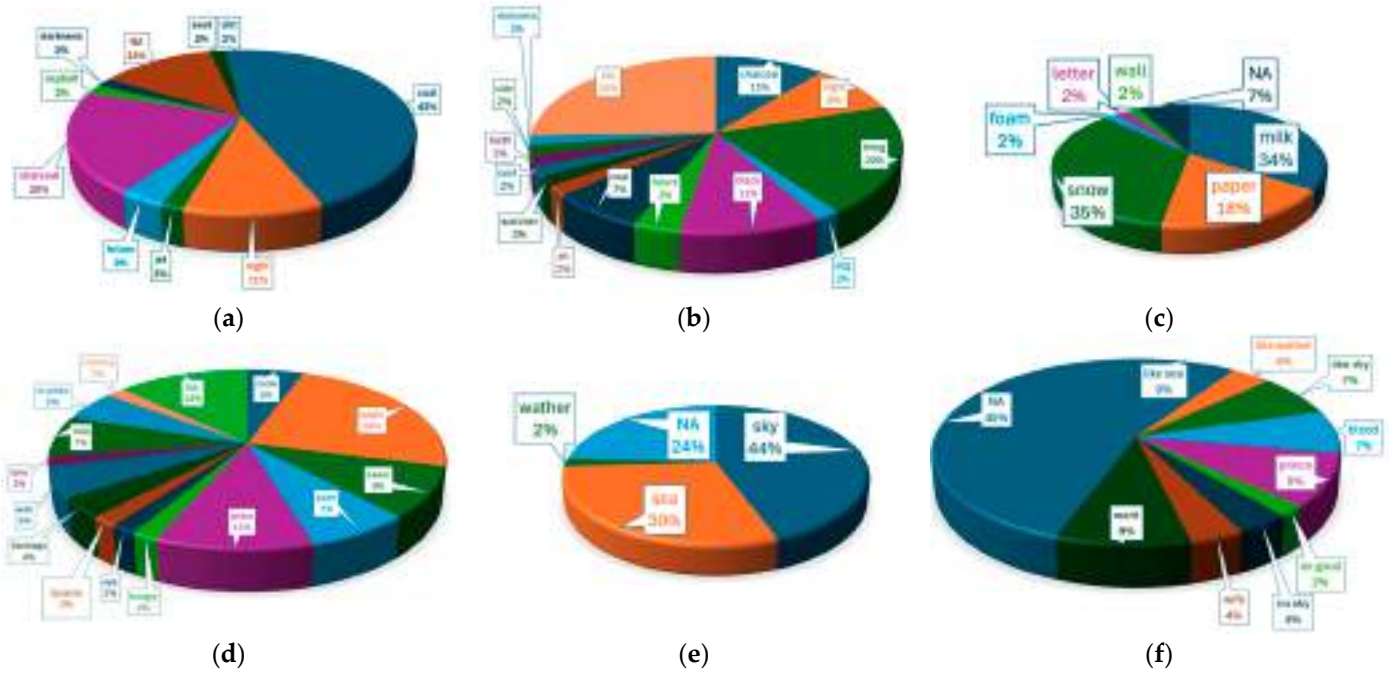


Figure 6. Results from SO3. IdSurvey for (**a**) dimension "Colours". Black as…; (**b**) black as idioms and proverbs by percentages; (**c**) white as…; (**d**) white as idioms and proverbs by percentages; (**e**) blue as…; (**f**) blue as idioms and proverbs by percentages.

The analysis of the white attribute had a strong prevalence for nature-based comparisons: "*milk/leche*" and "*snow/nieve*" were equally cited by 35% of respondents (Figure 6c). "*Paper/papel*" was the third most common comparison (18%), typically signifying paleness or shock. The most common white idiom code was "*bottle/botella*" (24%), linked to "*Blanco y en botella*"/*Cut and dry*, indicating clarity or obviousness (Figure 6d).

For the colour blue, comparative constructions were heavily associated with nature: "*sky/cielo*" (44% responses). This was the primary reference point, followed by "*sea/mar*" (30%) (Figure 6e). However, almost half of the idiomatic responses (45% responses) were categorised as No Answer (NA) (Figure 6f). Among the idioms provided, prince ("*Príncipe azul*"/*Prince Charming*) and the proverb linked to want ("*El que quiera azul celeste, que le cueste*"/*Whoever wants sky blue, it will cost them*) comprised the highest frequency of responses (9% each).

The attribute red showed a clear consensus in the comparisons provided: "*tomato/tomate*" accounted for nearly half of the responses (48%), while "*blood/sangre*" constituted 24%. In the idioms section, "tomato/tomate" was the leading specific code (29%), often referring to blushing or turning red, tying with No Answer (NA) for the overall highest frequency. For the term reddish, "*tomato/tomate*" dominated again with comparative responses (42%). Nevertheless, No Answer (NA) was overwhelmingly frequent in the idiom section, accounting for 69% of the total, suggesting low familiarity with codified "Reddish" proverbs. Finally, the comparison for pale was frequently associated with "*wall/pared*" (20%), followed closely by "*paper/papel*" (18%) and "*ghost/fantasma*" (17%). For idioms related to paleness, NA was the most dominant

response (48%). Excluding NA, the "*wall/pared*" (11%) was the most cited idiom, often used in phrases like "*Pálido como la pared*"/*Pale as the wall*.

These detailed manual findings contributed to the identification of an MWE corpus, which was subsequently classified into five groups (Walsh et al. 2018, Figure 3). This corpus is analysed in the following paragraphs (Section Deep Manual Analysis of Black and White Attributes).

Attributes from Dimension "Physical Aspects"

The analysis of attributes within the Physical Aspects dimension focused on the MWEs and comparisons related to the attributes "*Small as…*" and "*Tall as…*", utilising data collected from $n = 54$ students.

The analysis of the *Small as…* comparative constructions revealed that the *ant* was the predominant comparison, cited by 30% of respondents, followed by *mouse* and *dwarf* (9% and 7%, respectively). When grouped into broader categories, animals constituted the largest grouping (48%), far surpassing people (15%), cartoons (7%), and things and food (both 6%). A notable 19% of participants provided no answer (NA) for the initial comparison.

The subsequent analysis of idioms and proverbs related to "smallness" found that the majority of responses were categorised as no answer (NA), accounting for 63% of the $n = 43$ coded phrases. Among the specific proverbs identified, the most frequent code was *perfume* (9%), which summarises expressions linking small size to high quality, such as "*Los buenos perfumes van en frascos pequeños*"/*Good perfume comes in small bottles.* The third most frequent code was *bully* (7%), tied to the idiom "*Pequeño pero matón*"/*Small but bully.*

The concept of smallness carried varying connotations, being perceived as either positive ("Very important, highly valued") or negative ("Very insignificant, no value," or "Lazy"). Table 3 provides examples of comparisons related to smallness, including negative connotations.

Table 3. IdSurvey for the dimension "Physical Attributes": small-as comparisons.

Spanish Code—Spanish	English
MESI—Pequeño como Messi	Small like Messi
PEA—Pequeño como un guisante	Small like a pea
CHICKPEA—Es igual de pequeño que un garbanzo	As small as a chickpea
NAIL—Más pequeño que una uña	Smaller than a fingernail
DWARF—Pequeño como un enano	Small as a dwarf
DWARF—Eres tan pequeño como un enano	You are as small as a dwarf
ANT—Pequeño como una hormiga	Small as an ant
MOUSE—Pequeño como un ratón	Small as a mouse
RICE—Pequeño como un grano de arroz	Small as a grain of rice
BUTTON—Pequeño como un botón	Small as a button

Regarding the attribute *Tall like (as)*, a strong consensus favoured "*una jirafa*"/*giraffe* as the dominant comparison. This was cited by 39% of students. The next most frequent comparisons were *pine* and *tree* (both 9%). Similarly to the analysis of "smallness", there was a high rate of non-response (NA), accounting for 17% of the comparisons provided. The idiomatic analysis of "tallness" showed that 43% of responses were coded as NA, meaning that nearly half of the students did not think of a relevant idiom or proverb. The highest frequency among actual MWEs was a tie (7% each) between the codes *climb* (referring to phrases about ascending, e.g., "*Cuanto más alto se sube, más grande es la caída*"/*The higher you climb, the harder you fall* and *pine* (referring to phrases like "*Alto como un pino*"/*Tall as a pine*). Other codes included *skyscraper* (6%) and *giraffe* and *lamp* (4% each).

This analysis revealed that some responses were not traditional MWEs but descriptive comparisons, such as "*Tall as an elf*", which could have been influenced by popular culture.

Deep Manual Analysis of Black and White Attributes

Utilising the classification system developed by Walsh et al. (2018) to categorise linguistic idiosyncrasies, a total corpus of 48 sentences was obtained. These sentences were categorised into five distinct groups (Appendix D), highlighting the linguistic diversity found.

Figurative comparisons (similes or idioms) include vivid and culturally accepted comparisons (Appendix D.1, Figure A6). A total of 11 sentences were identified. Examples related to blackness often involved coal (e.g., "*Más negro que el carbón*"/*Black as coal*), while whiteness comparisons included terms like paper ("*Blanco como el papel*"/*White like a sheet*), wall, and lime *("Blanco como la cal*"/*White as lime*).

Expressions of obviousness or cultural irony clarify points considered self-evident, thereby enhancing understanding. A total of 11 sentences were classified into this group. Blackness was associated with charcoal ("*Negro como el tizón*"/*Black as a charcoal*), and night ("*Negro como la noche*"/*Black as night*). Expressions signifying worry or pessimism (such as "*La cosa está muy negra*"/*The thing is very black* or "*Lo veo negro*"/ *It looks dark*) were also included here (Appendix D.1, Figure A6).

Metaphors related to literal meaning add deeper connotations that extend beyond literal interpretation. This category contained eight sentences. Examples include describing someone with a tan (e.g., "*Este verano se ha puesto negro tizón*"/*This summer he/she has turned as black as coal*), or referring to paleness using comparisons to snow (e.g., "*Quedó blanco como la nieve*"/*He was white as snow*), paper, wall, or milk, such as "*Te has quedado blanco como la leche*"/*You've turned white as milk*.

Idiomatic metaphors (Appendix D.2, Figure A7) are expressions with a meaning that is not directly alluded to by the literal meaning of the words. A total of 11 sentences were identified in this category. Black-related idioms frequently described getting angry (e.g., "*Me pones negro*"/*You make me go black*) or having an uncertain future (e.g., "*Negro como tu futuro*"/*Black as your future*). White-related idiomatic metaphors included dressing elegantly (e.g., "*Ir de punta en blanco*"/*Dress to the nines*), achieving success (e.g., "*Dar en el blanco*"/ *Hit the target*), and suddenly forgetting something (e.g., "*Quedarse en blanco*"/*Go blank*).

The final category, proverbial expressions or popular sayings, comprises proverbs, which are used to impart moral or cultural messages succinctly (Appendix D.2, Figure A7). A total of seven sentences were identified. These included sayings about the perseverance required to achieve goals (e.g., "*Por dinero baila el perro, y por pan si es negro*"/*For money the dog dances, and for bread if it is black*), and maintaining a sense of one's true nature regardless of appearance (e.g., "*Aunque la mona se vista de seda, mona se queda y aunque la pinten de blanco, mona sigue siendo*"/*Although the monkey is dressed in silk, mona stays, and even though it is painted white, monkey remains*). This category also covered the expression "*Blanco y en botella*"/*Cut and dry*, denoting clarity, as well as sentences with rhetorical questions involving the white horses of Saint Santiago (drawing on a Catholic religious background) and Don Quixote (drawing on a Spanish literary background).

3.4.2. Large-Scale Treatment and Results

The analysis included 34 attributes in individual dynamic tables (Annex 7 of the BA). Appendix E (Figure A8) presents these dynamic tables, including the most frequently encountered comparative nouns. The key findings for central attributes include those previously analysed from the "Colours" dimension and the "Tall" and "Small" attributes from

the "Physical Aspects" dimension. The attribute *Small* is primarily associated with an *ant*, but also includes *chickpea*, *mouse*, and the fictional character *Minion*. Moreover, pivot tables extracted additional sentences for this dimension, covering the attributes "Thin", "Slow", and "Quick/Fast". For the concept "Thin", comparisons with a stick and a noodle are the most common; however, links with a stick and a small *stick* are also frequent in sentences such as "*Delgado como un palo*"/*Thin as a stick*, "*Delgado como un palito*"/*Thin as a small stick*, "*Delgado como un espárrago*"/*Thin as an asparagus*, or "*Delgado como un alfiler*"/*Thin as a pin*. For the word "Slow", frequent associations were found with a *turtle* and a *snail*, as well as the idiomatic expression "*Lento como el caballo del malo*"/ *Slow as the villain's horse*.

"Quick/Fast" is mainly linked to the wind, as in the idiom *Rápido como el viento*/ *Fast as the wind*. Less frequent but apparent associations include "*Rápido como un pepino*"/*Fast as a cucumber*, *Rápido como una roca*/*Fast as a rocket*, "*Rápido como flash*"/*Fast as a flash*, and "*Rápido como Rayo McQueen*"/*Fast as Lightning McQueen* (a fictional character). Mental and emotional states such as "Crazy" are overwhelmingly linked to a goat (e.g., *Crazy as a goat*); "Smart" is most often associated with Einstein; and "Happy" can be found in the idiom *Feliz como una perdiz*/*Happy as a partridge*. Other qualities include "Drunk", mainly compared to a vat (a barrel) in "*Borracho como una cuba*"/*Drunk as a vat*, and "Strong", which involves comparisons to *vinegar*, a *rock*, an *oak tree*, and *steel*. Finally, the attribute "Clean" is linked to idioms like "*Limpio como los chorros del oro*"/*Clean as a whistle*.

4. Discussion and Conclusions

This study provides a holistic understanding of the pedagogical potential of AR technologies, specifically the AR Flashcards application. It yields several key discussion points related to quality, utility, user experience, psycho-pedagogical characteristics, and the role of diversity in digital learning.

The findings strongly support the utility of well-designed AR tools in education. Users reported an exceptionally positive experience regarding the application's quality and usefulness. Surveys provided a near-unanimous agreement on clarity, functionality, and satisfaction. This outcome confirms the system's success in meeting user expectations and establishes its potential as an accessible and effective educational tool, echoing similar conclusions in the previous literature (Cabero and Barroso 2016).

Crucially, participants demonstrated a strong appreciation for the integrated AR experience, valuing both the digital application and the tangible flashcards. This reinforces the benefits of combining physical interaction with digital platforms to promote motivation and active learning (Cabero-Almenara et al. 2021; Castellanos and Pérez 2017). The success of the AR Flashcards system, in terms of its psycho-pedagogical characteristics, results from its ability to merge visual, experiential, and linguistic components, thereby fostering both engagement and comprehension (Prendes 2015; Barba et al. 2015). This balance between innovation and usability appears fundamental to creating an effective, interactive, and integrated learning environment.

Despite the high general satisfaction, participants provided constructive feedback, emphasising clear demands for improved usability, interactivity, and accessibility. Many of these suggestions focused on specific psycho-pedagogical and didactic dimensions, such as the need for simpler navigation, enhanced interactivity, and better adaptation for specific learner groups. Such insights reinforce the importance of designing inclusive educational technologies. This is a cornerstone of effective digital learning environments advocated for by Alba (2019) and Cabero and Córdoba (2009). Recent developments highlight that linguistic diversity must be systematically addressed in language technologies. As Savary et al. (2025) emphasised, current NLP advances should not compromise the preservation and promotion of under-resourced languages. Thus, flexible architectures are required that adapt to diverse linguistic structures, as evidenced by this research. In

this sense, Quesada (2025) argues that technologies should be co-created with communities, ensuring that meaning, community agency, and heritage guide technological design. This approach supports the systematisation of a teaching–learning process considering the plurilingual competence of AR and its potential for inclusion, enabling all languages to participate in the digital transformation.

The widespread interest among users in extending AR applications across diverse disciplines—including mathematics, sciences, and languages—underscores the perceived versatility and scalability of this technology for broader educational purposes (Cabero-Almenara et al. 2022; Parmaxi et al. 2024).

The limitations of this study are rooted in its methodology, sample constraints, and the inherent difficulties in linguistic data collection. The research explicitly avoids statistical inferences to the broader population, undertaken through an initial non-systematic process. The innovation of this study lies in its proposal of a final systematic approach to the procedure, which will support future research in related areas. Despite involving 220 students, the sample exhibited a marked gender imbalance, with a predominance of female students.

A significant constraint in identifying the MWE corpus was the high frequency of "No Answer" (NA) responses across the IdSurvey's idiom sections (e.g., reaching 69% for reddish idioms), indicating limited student familiarity with many codified proverbs. Due to the complexity of the qualitative data, analysis heavily utilised LLMs, necessitating rigorous, iterative human review to eliminate inaccuracies and instances of hallucinated responses, with some initial LLM outputs being deemed unreliable. In line with observations by Burger et al. (2023) and Goyanes et al. (2025), careful human supervision is essential to ensure both accuracy and ethical validity when employing artificial intelligence in data analysis. Finally, user feedback highlighted technical limitations of the AR resource, including issues concerning cross-platform compatibility (lack of iOS support), large file size, and slow performance. Technical limitations (Anil et al. 2025; Schorr et al. 2024) highlight the need to continue working on this aspect.

A critical dimension emphasised in this study is the role of multilingualism and idiosyncrasies in enriching components of educational diversity. These findings, with a perceived usefulness rate of 94%, support multimodal learning. Integrated AR experiences promote active engagement through combined digital and physical interactions. However, the 69% "no response" rate for certain idiomatic expressions, quoted in the last paragraph, reveals a critical limitation for linguistic diversity and cultural heritage preservation; despite technological accessibility, culturally embedded language remains inaccessible to learners. This tension indicates that digital inclusion cannot be measured solely through usability or satisfaction, as multimodal tools may inadvertently reproduce linguistic exclusion. Addressing this gap underscores the need for co-creative approaches that more effectively align digital affordances with linguistic diversity and cultural memory.

Multilingual learning has been shown to foster cognitive flexibility and enhance intercultural understanding (Calzati and De Kerckhove 2024; Jayanath 2020). Furthermore, exploring idiosyncratic linguistic variations, such as idioms and proverbs, offers a mechanism through which cultural and linguistic differences can effectively promote inclusivity in the classroom. Consequently, a promising direction for future research and development involves the integration of multilingual and culturally responsive modules into AR environments. Within its exploratory scope, the findings suggest that mobile AR effectively enhances idiomatic comprehension among undergraduates. While results indicate high perceived utility, significant non-response rates reflect limited idiomatic familiarity, necessitating localised pedagogical reinforcement. Ultimately, while the system is perceived as highly clear and useful, its successful scalability to other disciplines depends

on addressing technical limitations such as cross-platform compatibility and storage requirements.

Future research should advance the integration of community-centred and multilingual frameworks within AR environments. The promotion of universality through diversity strengthens social cohesion (Quesada 2025; Savary et al. 2025). The adoption of multilingual and multimodal digital materials is not only imperative to foster plurilingualism and the digital transition (Calzati and De Kerckhove 2024) but also necessary given that linguistic diversity in higher education is an established reality. Looking ahead, the results of this study invite educators, designers, innovators, and researchers to continue advancing along this promising pathway. Building on the solid foundations established here, the challenge is to continue exploring, refining, and expanding the creative potential of AR so that every learner, regardless of their background or language, can experience the joy of linguistic and cultural discovery in a truly connected digital world.

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Institutional Review Board Statement: In Title 1, Article 3, of the Comité de Ética de Investigación (CEI) de la Universidad de Murcia, it states that research involving human subjects is only evaluated. Therefore, this research does not require an ethics statement since it is data from an Educational Sciences and Humanities project, where the data has been anonymised and informed consent has been obtained.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study with a written informed consent for data publication according to the protocol of the Universidad de Murcia (Annex 31, BA, available at https://doi.org/10.5281/zenodo.17463094).

Data Availability Statement: Research data are shared at https://doi.org/10.5281/zenodo.17463094.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AR	Augmented Reality
AR+	AR Flashcards Questionnaire
BA	Book of Annexes
CP	Simultaneous Academic Programme of Double Degree with Specific Itinerary of Degree in Early Childhood Education and Degree in Primary Education
GenAI	Generative Artificial Intelligence
IdSurvey	Idiosyncrasy Survey

LLMs	Large Language Models
PB	Degree in Primary Education. Bilingual Group
PDPC	Personal Data Protection Commission Singapore
PE	Pedagogy Degree
PS	Double Degree in Primary Education and Physical Activity and Sport Sciences
PT	Degree in Primary Education. Mention in Therapeutic Pedagogy
MWE	Multiword Expressions
UM	University of Murcia

Appendix A

Appendix A.1

Table A1. AR+ data coding.

Nº	Item	Code	Item Type/Values
1	By completing this form, do you confirm your consent to the analysis of your responses?	CONSENT	CONSENT
2	University, Group	LOCATION	Open/finally categorised as subject codes
3	Gender	GENDER	Close; multiple options with simple answer/Female, Male, Prefer not to say
4	What did you like the most?	LIKE	Mixed; multiple options with simple answers/Cards, Application, Content. Open/Others, finally categorised as "All"
5	How clear are the tasks/scenarios?	CLEAR	Mixed; multiple option, with simple answer; Likert scale/Clear: Extremely, very, moderately, not very, not at all. Open/Other, finally categorised as "Unclear terms"
6	What captures your attention the most?	ATTENTION	Mixed; multiple options with simple answers/ The card's design, The app's content, The technical part of app. Open/Other (not used)
7	How satisfied were you with the application?	QUALITY	Mixed; multiple options with simple answers; Likert scale/Satisfied: Extremely, Very, Somewhat, Neutral. Dissatisfied: Somewhat, Very, Extremely. Open/Other (not used)
8	How useful do you consider the application?	USEFUL	Mixed; multiple options with simple answers; Likert scale/Useful: extremely, very, moderately, not very, not useful. Open/Other. Other (not used)
9	What did you not like about the application?	DISLIKE	Open/finally categorised
10	Which lessons would you like to see AR applications for?	LESSONS	Open/finally categorised
11	Other suggestions, recommendations, requests	OTHER	Open/finally categorised

Appendix A.2

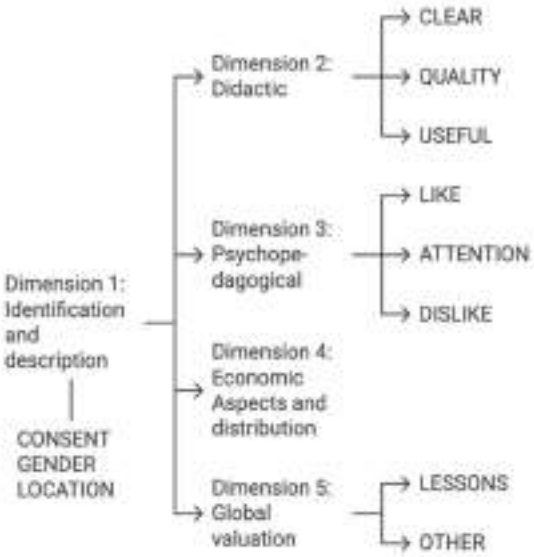


Figure A1. AR+ Classifying data. Evaluation's dimensions based on Martínez Sánchez et al. (2002).

Appendix B

Appendix B.1

Table A2. IdSurvey data coding. Blocks, attributes, variables, and item type.

Block	Attributes	Variable/Scale	Item Type
Variable type: DESCRIPTIVE			
1 Consent	no	Qualitative, dependent. Categorical. Dichotomous/Nominal	Closed
2 Date of birth	no	Quantitative. Independent. Continuous. Categorical/Interval	Closed
3 Gender	no	Qualitative, independent. Categorical/Nominal	Mixed
4 Name, surname	no	Qualitative, independent. Categorical/Nominal	Open
5 Languages spoken	no	Qualitative, independent. Categorical/Nominal	Open
Variable type: COMPLEX			
6 Colours	White, Black, Blue, Red, Reddish, Pale	Qualitative, independent. Categorical/Nominal	Open
7 Aspects of the body	Tall, Small, Fat, Thin or Slim, Beautiful, Handsome or Pretty, Ugly, Strong, Weak, Quick or Fast, Slow, Blind, Deaf		
8 Intellect	Smart or Intelligent, Crazy, Fool/Stupid, Naive		
9 Behaviour	Lazy, Hardworking, Sly or Cunning, Clumsy, Ashamed or Embarrassed, Patient, Curious, Rude, Caring or Considerate, Stubborn, Brave or Courageous, Tearful or Scared, Bold or Imprudent, Humble, Respectful, Honest, Liar or Dishonest		
10 Health and well-being	Healthy, Sick or Ill, Tired, Hungry, Full or Satiated, Drunk, Sober		
11 Moral and ethical	Good, Bad, Saint or Holy		
12 Aged-related	Young, Old		
13 Comparative attributions	Similar, Different, Cheap, Rich		
14 Emotional states	Happy, Cheerful or Joyful, Sad, Disgusted, Frustrated, Tearful or Scared		
15 Cleanliness	Dirty, Clean		
16 Personality traits	Lovely		

Appendix B.2

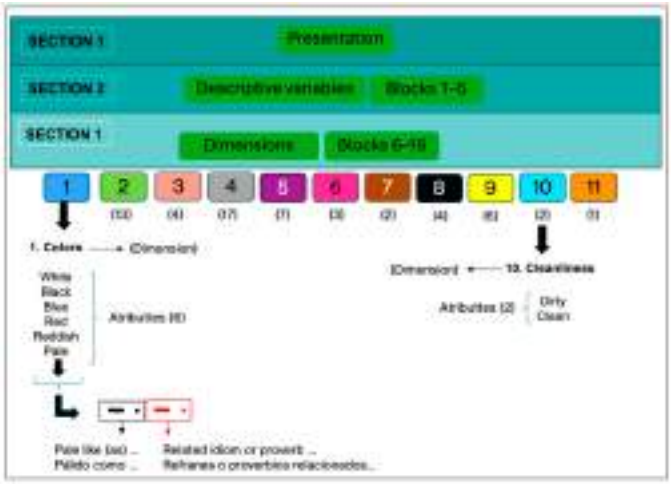


Figure A2. IdSurvey. Qualitative structure, dimensions, and attributes based on Zaicovskaya (1998, pp. 235–37).

Appendix C

Appendix C.1

Figure A3. Some teaching materials.

Appendix C.2

Figure A4. Practical experience in the Faculty of Education.

Appendix C.3

Figure A5. Multilingual AR flashcards.

Appendix D

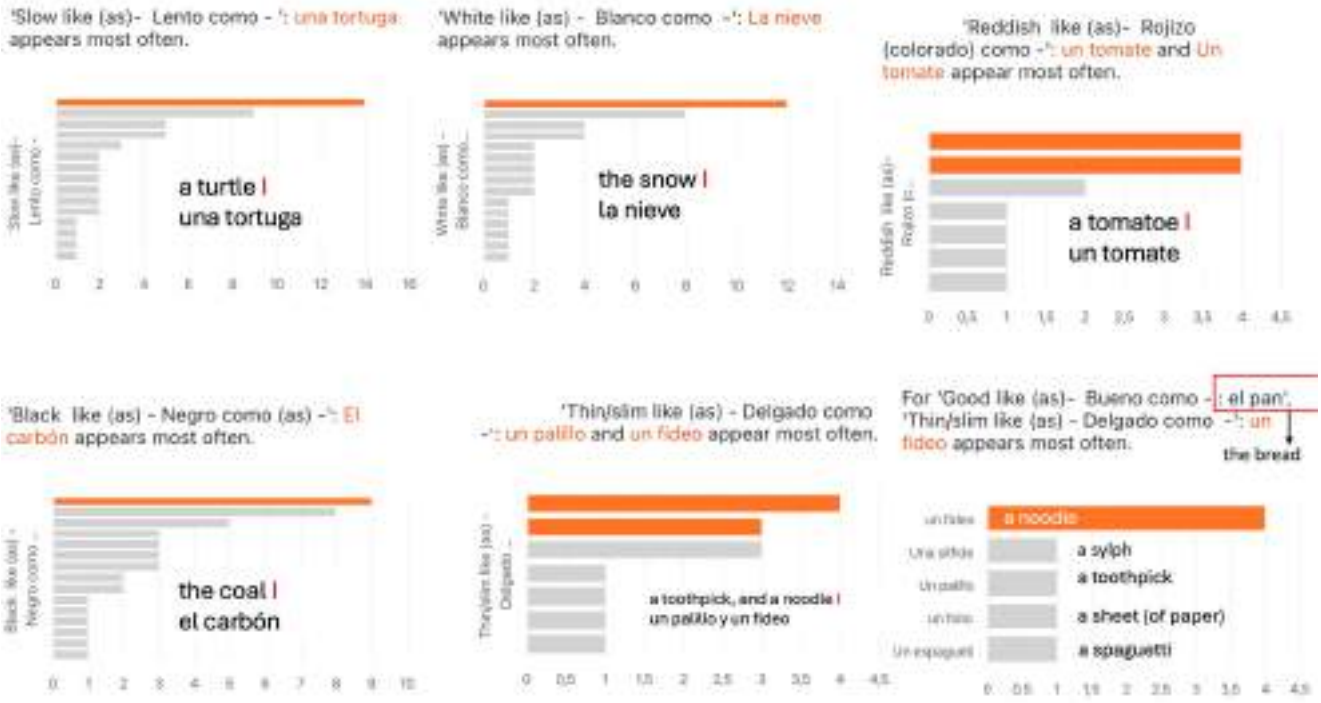
Appendix D.1

Figure A6. Figurative comparisons, expressions, and metaphors.

Appendix D.2

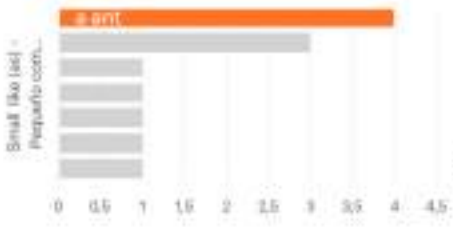
Figure A7. Idiomatic metaphors and proverbial expressions.

Appendix E



'Red like (as) - Rojo como -': Rojo como un tomate and Un tomate appear most often.

'Small like (as) - Pequeño como -': una hormiga appears most often.

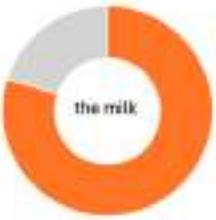


For 'Sly or Cunning like (as)- Astuto como -: un zorro', 'Blue like (as) - Azul como (as) -': El cielo and El mar appear most often.

the fox

'Blue like (as) - Azul como (as) -': el cielo and El mar appear most often.

la leche accounts for the majority of 'White like (as) - Blanco como -'.



'Quick or Fast like (as)- Rápido o veloz como -': El viento appears most often.

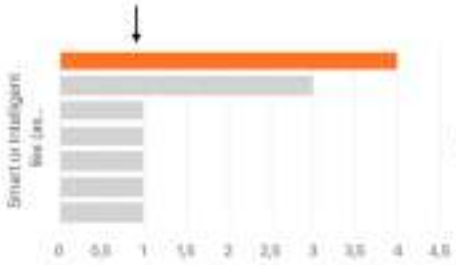
una perdiz accounts for the majority of HAPPY

una cuba accounts for the majority of 'Drunk like (as)- Borracho como-'.

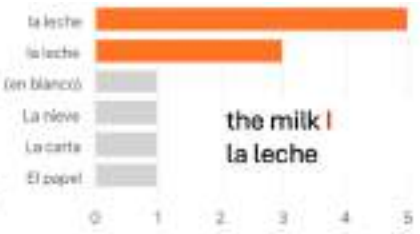
la noche accounts for the majority of 'Young like (as)- Joven como-'.

'Crazy like (as)- Loco como': una cabra appears most often.

'Smart or Intelligent like (as)- Listo como - ': Einstein appears most often.



'White like (as) - Blanco como -': la leche and la leche appear most often.



https://doi.org/10.3390/socsci15020062

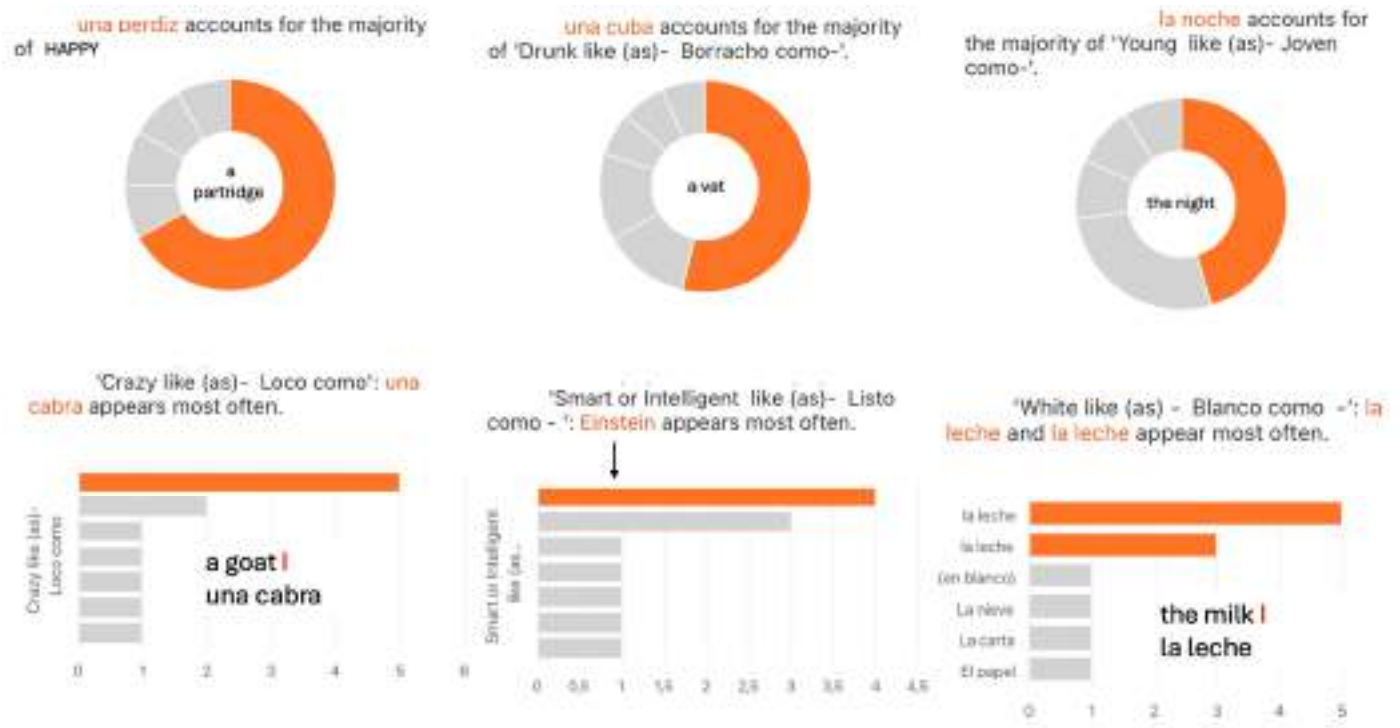


Figure A8. IdSurvey. Most frequently used terms for attributes and graphics.

References

Alba, Carmen. 2019. Diseño Universal para el Aprendizaje: Un modelo teórico-práctico para una educación inclusiva de calidad. *Participación Educativa* 9: 55–68.

Anil, Nikhil, Seyed Reza Shahamiri, and Nasser Giacaman. 2025. Dynamic Sign Language Recognition Through an Augmented Reality Environment. In *Neural Information Processing* (*ICONIP 2024*). Edited by Mufti Mahmud, Maryam Doborjeh, Kevin Wong, Andrew Chi Sing Leung, Zhorhe Doborjeh and Muhammad Tanveer. Singapore: Springer Nature, vol. 3, pp. 354–68. https://doi.org/10.1007/978-981-96-6582-2_24.

Barba, Ruth Genoveva, Saul Yasaca, and Carlos Anibal Manosalvas. 2015. Impacto de la realidad aumentada móvil en el proceso enseñanza-aprendizaje de estudiantes universitarios del área de medicina. In *Investigar con y para la Sociedad*. Edited by AIDIPE. Madrid: Bubok, vol. 3, pp. 1421–29. Available online: https://lc.cx/KSfngy (accessed on 16 January 2026).

Beirak, Jazmín. 2025. *Plan de Derechos Culturales 2025–2030*. Madrid: Ministerio de Cultura. Available online: http://bit.ly/47nN3rl (accessed on 16 January 2026).

Burger, Bastian, Dominik K. Kanbach, Sascha Kraus, Matthias Breier, and Vincenzo Corvello. 2023. On the use of AI-based tools like ChatGPT to support management research. *European Journal of Innovation Management* 7: 233–41. https://doi.org/10.1108/EJIM-02-2023-0156.

Cabero, Julio, and Julio Barroso. 2016. The educational possibilities of Augmented Reality. *Journal of New Approaches in Educational Research* 5: 44–50. https://doi.org/10.7821/naer.2016.1.140.

Cabero, Julio, and Margarita Córdoba. 2009. Inclusión educativa: Inclusión digital. *REI—Revista de Educación Inclusiva* 1: 61–77. Available online: https://lc.cx/eqcRDK (accessed on 16 January 2026).

Cabero, Julio, Julio Barroso, and Carmen Llorente. 2019. La realidad aumentada en la enseñanza universitaria. *REDU—Revista de Docencia Universitaria* 1: 105–18. https://doi.org/10.4995/redu.2019.11256.

Cabero-Almenara, Julio, Esteban Vázquez-Cano, Wellington Remigio Villota-Oyarvide, and Eloy López-Meneses. 2021. Innovation in the University Classroom Through Augmented Reality. Analysis From the Perspective of the Spanish and Latin American Students. *Revista Electrónica Educare* 3: 1–17. https://doi.org/10.15359/ree.25-3.1.

Cabero-Almenara, Julio, Rubicelia Valencia-Ortiz, and Carmen Llorente-Cejudo. 2022. Ecosistema de tecnologías emergentes: Realidad aumentada, virtual y mixta. *Revista Tecnología Ciencia y Educación* 23: 7–22. https://doi.org/10.51302/tce.2022.1148.

Calle, Aldrin Jefferson, Gabriela Yuleisy Lino, Ángel Gabriel Ruiz, and Tangie Mayerli Guagcha. 2024. Diseño de cuestionarios efectivos en investigación de mercados: Enfoque en preguntas abiertas vs. cerradas. *Ciencia y Desarrollo* 1: 17–29.

Calzati, Stefano, and Derrick De Kerckhove. 2024. *Quantum Ecology. Why and How New Information Tecnologies Will Reshape Societies*. Cambridge, MA: The MIT Press. https://doi.org/10.7551/mitpress/14061.003.0001.

Castellanos, Almudena, and Carlota Pérez. 2017. New Challenge in Education: Enhancing Student's Knowledge through Augmented Reality. In *Augmented Reality. Reflections on Its Contribution to Knowledge Formation*. Edited by José María Ariso. Berlin and Boston: De Gruyter, pp. 273–93. https://doi.org/10.1515/9783110497656-015.

CEFR. 2023. *A Guide to Action-Oriented, Plurilingual and Intercultural Education*. Strasbourg: Council of Europe Publishing. Available online: https://short.do/bpdN0E (accessed on 16 January 2026).

Cesmeli, Artun. 2023. The Metaverse: A Brave New "World". *Journal of AI* 1: 32–51. https://doi.org/10.61969/jai.1318812.

Chaljub-Hasbún, Jeanette, Lucía Amorós-Poveda, and Jacqueline Vega. 2024. El metaverso: Un ejemplo de implementación docente en la República Dominicana. In *Tecnología Educativa para una Sociedad Multimodal. Libro de actas EDUTEC'24.* Edited by Julio Cabero-Almenara, Antonio de Padua Palacios-Rodríguez, Marta Montenegro-Rueda and José Fernández Cerero. Sevilla: Universidad de Sevilla—Grupo de Investigación Didáctica, pp. 271–75. Available online: http://bit.ly/4qEON8O (accessed on 16 January 2026).

Chew, Robert, John Bollenbacher, Michael Wenger, and Annice Kim. 2023. LLM-Assisted Content Analysis: Using Large Language Models to Support Deductive Coding. *arXiv* arXiv:2306.14924.

Council of Europe. 2020. *Common European Framework of Reference for Languages: Learning, Teaching, Assessment—Companion Volumen*. Strasbourg: Council of Europe Publishing. Available online: www.coe.int/lang-cefr (accessed on 16 January 2026).

Council of the European Union. 2018. Council Recommendation of 22 May 2018 on key competences for lifelong learning. *Official Journal of the European Union* C 189/1: 1–13. Available online: https://n9.cl/rv9zme (accessed on 16 January 2026).

Council of the European Union. 2019a. Council Recommendation of 22 May 2019 on High-Quality Early Chilhood Education and Care Systems. *Official Journal of the European Union* C 189/4: 4–14. Available online: https://short.do/bM-rHD (accessed on 16 January 2026).

Council of the European Union. 2019b. Council Recommendation of 22 May 2019 on a comprehensive approach to the teaching and learning of languages. *Official Journal of the European Union* C 189/15: 15–22. Available online: https://short.do/ApKdOz (accessed on 16 January 2026).

Creswell, John W., and Vicki L. Plano Clark. 2007. *Designing and Conducting Mixed Methods Research*, 3rd ed. Thousand Oaks: Sage Publications.

Dewaele, Jean-Marc. 2015. Bilingualism and Multilingualism. In *The International Encyclopedia of Language and Social Interaction.* Edited by Karen Tracy, Cornelia Ilie and Todd Sandel. Hoboken: John Wiley & Sons, pp. 1–11. https://doi.org/10.1002/9781118611463.wbielsi108.

Dibekulu, Dawit. 2020. An Overview of Data Analysis and Interpretations in Research. *International. Journal of Academic Research in Education and Review* 1: 1–27.

European Commission. El Multilingüismo como Competencia Clave. European Education Area. September 19. Available online: https://n9.cl/multilinguismo (accessed on 16 January 2026).

Gao, Tianyu, Adam Fisch, and Danqi Chen. 2021. Making Pre-trained Language Models Better Few-shot Learners. *arXiv* arXiv:2012.15723.

González Calatayud, V. 2024. Uso y aplicaciones de la Inteligencia Artificial (IA) en la investigación educativa. In *Informe EDUTEC sobre Inteligencia Artificial y Educación*. Edited by Cordinated by Antono Bartolomé, Adolfina Pérez Garcias and María Paz Prendes-Espinosa. Palma de Mayorca: EDUTEC, pp. 47–51. Available online: http://bit.ly/3JyupFs (accessed on 16 January 2026).

Goyanes, Manuel, Carlos Lopezosa, and Beatriz Jordá. 2025. Thematic analysis of interview data with ChatGPT: Designing and testing a reliable research protocol for qualitative research. *Quality & Quantity* 59: 5491–510. https://doi.org/10.1007/s11135-025-02199-3.

Großmann, Anett, and Frank Hohmann. 2019. Static and Dynamic Input-Output Modelling with Microsoft Excel. Paper presented at SHAIO Sociedad Hispanoamericana de Análisis Input-Output Conference, Santiago de Compostela, September 11–13. Available online: http://bit.ly/4qda5dd (accessed on 20 October 2025).

Hernández-Leo, Davina, Pau Moreno, Jonathan Chacón, and Josep Blat. 2014. LdShake support for team-based learning design. *Computers in Human Behavior* 37: 402–12.

Ismailova, Gainigul, Klara Khassenova, Zarina Rakhmatullina, Gulnar Zhumadilova, and Shugyla Kenzhina. 2023. Multimedia Educational Environment as a Tool for Developing Communicative Competences in the Field of Trilingual Higher Education. *World Journal of English Language* 9: 31–39. https://doi.org/10.5430/wjel.v13n9p31.

Jayanath, Tharindu. 2020. A comparative study on bilingualism and multiculturalism. *Knowex Social Sciences Journal* 2: 79–91.

Joshi, Pratik, Sebastin Santy, Amar Budhiraja, Kalika Bali, and Monojit Choudhury. 2020. The State and Fate of Linguistic Diversity and Inclusion in the NLP World. Paper presented at 58th Annual Meeting of the Association for Computational Linguistics, Online, July 5–10. Stroudsburg: Association for Computational Linguistics, pp. 6282–93.

Kaur, S. P. 2013. Variables in research. *Indian Journal of Research and Reports in Medical Sciences* 4: 36–38. Available online: https://lc.cx/wS9IJE (accessed on 16 January 2026).

Keck, Casey, and Youjim Kim. 2014. *Pedagogical Grammar*. Amsterdam: John Benjamins.

Klatte, Aleana, Alexander Hradecky, Barbora Bromová, and Nii London. 2024. Every Language Matters: Building a More Inclusive Digital Future. Available online: https://lc.cx/SPN-xA (accessed on 20 October 2025).

Kothari, Charmy. 2004. *Research Methodology. Methods and Techniques*. New Delhi: New Age International.

Ling Lo, Mun. 2012. *Variation Theory and the Improvement of Teaching and Learning*. Acta Universitatis Gothoburgensis. Gothenburg: University of Gothenburg. Available online: https://n9.cl/mqzny (accessed on 16 January 2026).

Martínez Sánchez, Francisco, María Paz Prendes, Begoña Alfageme, Lucía Amorós, Trinidad Rodríguez Cifuentes, and Isabel María Solano. 2002. Herramienta de evaluación de multimedia didáctico. *Pixel-Bit Revista de Medios y Educación* 18: 71–88.

Mazur, Eric. 2024. *Peer Instruction*. Innovation in Teaching. Brighton: Harvard Bussiness Publishing. Available online: https://n9.cl/ydyyj (accessed on 16 January 2026).

Naveed, Humza, Asad Ullah Khan, Shi Qiu, Muhammed Saqib, Saeed Anwar, Muhammad Usman, Naveed Akhtar, Nick Barnes, and Ajmal Mian. 2024. A comprehensive overview of large language models. *arXiv* arXiv:2307.06435.

Ochoa, Carlos, and Manuel Molina. 2018. Estadística. Tipos de variables. Escalas de medida. *Evidencias en Pediatría* 29: 1–5. Available online: https://lc.cx/pk4ocO (accessed on 16 January 2026).

Padilla, David Blas, Esteban Vázquez-Cano, María Belén Morales, and Eloy López Meneses. 2019. Uso de apps de realidad aumentada en las aulas universitarias. *Campus Virtuales* 1: 37–48. Available online: https://n9.cl/t66x4r (accessed on 16 January 2026).

Pal, Sayak, Nitesh Tripathi, Sharmila Kayal, and Swati Agarwal. 2024. Measuring Reception of Advertising Endeavors through Quantitative Metrics. *Media Education (Mediaobrazovanie)* 3: 473–91. https://doi.org/10.13187/me.2024.3.473.

Parmaxi, Antigoni, Anke Berns, Lina Adinolfi, Alice Gruber, Mikhail Fominykh, Angeliki Voreopoulou, Fridolin Wild, Paraskevi Vassiliou, Eirini Christou, Concepción Valero-Franco, and et al. 2024. Augmented Reality in Language Learning: Practical Implications for Researchers and Practitioners. In *Learning and Collaboration Technologies*. Edited by Panayiotis Zaphiris, and Andri Ioannou. Washington: Springer, vol. 3, pp. 138–54. https://doi.org/10.1007/978-3-031-61691-4_10.

Personal Data Protection Commission Singapure (PDPC). 2022. *Guía Básica de Anonimización. División de Innovación Tecnológica*. Madrid: AEPD. Available online: https://www.aepd.es/documento/guia-basica-anonimizacion.pdf (accessed on 16 January 2026).

Prendes, Carlos. 2015. Realidad aumentada y educación: Análisis de experiencias prácticas. *Píxel-Bit Revista de Medios y Educación* 46: 187–203. Available online: https://www.redalyc.org/pdf/368/36832959008.pdf (accessed on 16 January 2026).

Putra, Alfyananda Kurnia, Sumarmi Sumarmi, Alfi Sahrina, Azni Fajrilia, Muhammad Naufal Islam, and Batchuluun Yembuu. 2021. Effect of Mobile-Augmented Reality (MAR) in Digital Encyclopedia on The Complex Problem Solving and Attitudes of Undergraduate Student. *International Journal of Emerging Technologies in Learning* 7: 119–34. https://doi.org/10.3991/ijet.v16i07.21223.

Quesada, José Francisco. 2025. AI Thinking as a Meaning-Centered Framework: Reimagining Language Technologies Through Community Agency. *arXiv* arXiv:2502.14923v1.

Rauschnabel, Philipp A., Reto Felix, Chris Hinsch, Hamza Shahab, and Florian Alt. 2022. What is XR? Towards a Framework for Augmented and Virtual Reality. *Computers in Human Behavior* 133: 107289. https://doi.org/10.1016/j.chb.2022.107289.

Savary, Agata, Daniel Zeman, Verginica Barbu Mititelu, Anabela Barreiro, Olesea Caftanatov, Marie-Catherine de Marneffe, Kaja Dobrovoljc, Gülşen Eryiğit, Voula Giouli, Bruno Guillaume, and et al. 2025. UniDive: A COST Action on Universality, Diversity and Idiosyncrasy in Language Technology. In *Proceedings of the 3rd Annual Meeting of the Special Interest Group on Under-Resourced Languages (LREC-COLING 2024)*. Edited by Maite Melero, Sakriani Sakti and Claudia Soria. Torino: ELRA and ICCL, pp. 372–82. Available online: https://aclanthology.org/2024.sigul-1.45/ (accessed on 16 January 2026).

Schorr, Isabel, David. A. Plecher, Christian Eichhorn, and Gudrun Klinker. 2024. Foreign language learning using augmented reality environments: A systematic review. *Frontiers in Virtual Reality 5*: 1288824. https://doi.org/10.3389/frvir.2024.1288824.

Shimul, Mehedi Hasan. 2024. How to Create Dynamic Table in Excel: 3 Quick Ways. Online. ExcelDemy. Available online: http://bit.ly/46Um9IR (accessed on 16 January 2026).

Suzuki, Wataru, and Neomi Storch, eds. 2020. *Language in Language Learning and Teaching. A Collection of Empirical Studies*. Amsterdam: John Benjamins Publishing Company.

Titchiev, Inga, Olesea Caftanatov, Veronica Iamandi, Dan Tălămbuță, and Daniela Caganovschi. 2023. An approach to Augmented Reality Classification and an example of its usage for application development with VAK learning styles Markers. *Computer Science Journal of Moldova* 2: 248–71. https://doi.org/10.56415/csjm.v31.13.

Van 't Hooft, Anuschka, and Silvia Romero-Contreras. 2025. Contributing to Indigenous Literacy: A "Trans" Approach in the Creation of Digital Learning Materials. *Journal of Research in Childhood Education* 2: 232–46. https://doi.org/10.1080/02568543.2025.2451069.

Walsh, Abigail, Claire Bonial, Kristina Geeraert, John P. McCrae, Nathan Schneider, and Clarissa Somers. 2018. Constructing an Annotated Corpus of Verbal MWEs for English. In *Proceedings of the Joint Workshop on Linguistic Annotation, Multiword Expressions and Constructions (LAW-MWE-CxG-2018)*. Edited by Agata Savary, Carlos Ramisch, Jena D. Hwang, Nathan Schneider, Melanie Andresen, Sameer Pradhan and Miriam R.L. Petruck. Santa Fe: Association for Computational Linguistics, pp. 193–200. Available online: https://aclanthology.org/W18-4921/ (accessed on 16 January 2026).

Xiao, Ziang, Xingdi Yuan, Q. Vera Liao, Rania Abdelghani, and Pierre-Yves Oudeyer. 2023. Supporting qualitative analysis with large language models: Combining codebook with GPT-3 for deductive coding. In *Proceedings of the 28th International Conference on Intelligent User Interfaces (IUI '23), Sydney, NSW, Australia, 27–31 March 2023*. New York: Association for Computing Machinery, pp. 75–78. https://doi.org/10.1145/3581754.3584136.

Zaicovskaya, Tamblltta. 1998. Etnokul'turnaya informatsiya v sravnitel'nykh konstruktsiyakh bolgar, moldavan i russkikh. In *Relatiile Moldo-Bulgare in Epoca Medie si Moderna*. Chișinău: Universitatea Pedagogica de Stat "Ion Creanga", pp. 227–39.