Mathematics and Sign Language Learning With a Tangible Game: An Inclusive Approach for DHH and Hearing Children

Cátia Casimiro, José Carlos Neves and Carla Sousa
Lusófona University, CICANT, Lisbon, Portugal

catia.casimiro@ulusofona.pt
josecsn@ulusofona.pt
carla.patricia.sousa@ulusofona.pt

Abstract: The purpose of this study was to investigate the potential of a tangible game, Inclusive Glossary of Mathematical Terms (GIM), to support the teaching of math and Portuguese sign language (*Língua Gestual Portuguesa*; LGP) to preschool and first-grade children, with an emphasis on inclusive education, knowledge acquisition, and engagement. GIM is composed of physical cards that are complemented by digital videos that run on an interface designed for this game. The game consists of two sets of cards and respective animations. As an inclusive math glossary, it also includes videos where concepts, characters, and objects are identified through images, words, and sign language. During the development process of GIM, it was possible to involve a multidisciplinary team, of which a Deaf sign language teacher and a sign language interpreter were part to ensure the clarity of the sign language and refine the written sentences accompanying the glossary. In order to validate its contents, a focus group of preschool and primary teachers specialized in the teaching of Deaf and Hard of Hearing (DHH) children was formed. A total of 120 children, aged between three and eight years old (M = 5.61; SD = 0.78), and seven LGP and special education teachers from three Portuguese schools participated in the study. The children used GIM in their classrooms, with the assistance of the participating teachers, who were subsequently interviewed to assess their engagement, interest, and learning outcomes. The interviews were analyzed using content analysis procedures, including descriptive statistics and Pearson correlations. The results indicated that GIM has the potential to effectively support the teaching of mathematics and LGP to preschool and first-grade children, especially in inclusive education contexts. The tangible nature of the game facilitated children's understanding of mathematical concepts and LGP, leading to improved involvement in the teaching-learning process. Moreover, the game promoted awareness of diversity and the principles of inclusive education, making it a valuable tool for promoting social inclusion and understanding. However, the study has reduced sample and context-specific limitations, suggesting a need for further research in this area.

Keywords: Game-based learning, Tangible game, Inclusive education, Mathematics, Sign language, Card game, Digital game

1. Introduction

There is still a lot of work to be done, in all areas of life, in terms of accessibility to eliminate the several barriers that people face when they are not met, such could be related to work, education, games, public services, etc. When we talk about the specific group of People with Disabilities and Deaf or Hard-of-Hearing (DHH) people the latter affirmation is even truer.

Considering that education is the foundation for the development of a person and their country, it must be accessible and inclusive to all people. Bearing in mind that different people have different needs, it is plausible to assume that different people will have different educational needs and so the educational system needs to be inclusive to meet the specific needs of each person. In the specific case of People with Disabilities and Deaf people, not having adequate education could lead, among others, to unemployment, lack of jobs, low income, and low communication skills. Communication is essential in everyday activities since it helps to create and maintain relationships, share experiences, express thoughts and feelings and learn (Wearmouth, 2016), so it is important to have high communication skills, which is only possible through inclusive education. Acknowledging the importance of inclusive education, the fourth objective of the Sustainable Development Goals (SDG) and the 2030 Agenda mention the importance of the right to inclusive and quality education (Granados et al., 2022).

Deaf people communicate with each other, essentially, through sign language, which is their native language. As such, teaching DHH children can be a challenge as it is inherent in teaching two languages, the sign language(s) and the written language of the country. It is noted that sign languages are the same as oral languages in the sense that both have their grammatical structure and rules and are used to communicate between people and their ideas and feelings, the only difference is that sign languages are visual-gestural languages, that is, the communication is through the use of gestures (signs) and visuality (Lacerda, Gràcia and Jarque, 2017).

Considering these premises, the current paper will focus on inclusive education, the use of Game-based Learning (GBL) in the early years of education, and how they can promote inclusive education and tangible games. The research will present the results of implementing the Inclusive Glossary of Mathematical Terms (*Glossário*

Inclusivo de Termos Matemáticos; GIM), which is a tangible game designed to support mathematics and sign language learning in classrooms.

1.1 Game-Based Learning and Tangible Games

GBL is an approach that leverages the motivational and engaging features of games to enhance learning outcomes (Plass et al., 2015). Games used for learning purposes have the advantage of creating a safe place for children, where they are not afraid to make mistakes, and that can provide them instant feedback – something that is of extreme importance in early education (Meyer, 2013). Games can also offer adaptive challenges and personalized learning experiences (Peirce, 2013) that cater to individual students' needs and diverse characteristics. Many studies have shown the benefits of GBL in improving learning outcomes in various subjects, such as science, engineering, and mathematics (Gao et al., 2020; Yu et al., 2022).

Tangible games are games that involve physical objects that can be manipulated and interacted with. In the specific case of GIM, the tangible objects are simultaneously game components and the user interface, framing it as a Tangible User Interface (TUI). One of the areas of application of TUIs is learning (Shaer and Hornecker, 2009), in the specific case of DHH children, who are visual learners, it could be advantageous to use TUIs in their learning process since it will allow them to touch what they are seeing digitally, it could also help children with motor disabilities through the use of the tangible parts. Essentially, it could help all children's learning process since the devices provide both physical and digital feedback which is important in early education (Meyer, 2013). As TUIs are used in a physical environment, it involves all senses of the child and as a consequence, it helps in their overall development (Shaer and Hornecker, 2009).

According to Shaer and Hornecker (2009), TUIs can benefit children with disabilities as they promote slower interaction, improve perceptual-motor skills, offer sensory experiences, facilitate collaboration, and empower children to have more control. This also suggests that TUIs offer greater opportunities for cognitive, linguistic, and social learning than exclusively graphical user interfaces.

1.2 Playfulness and the Learning Process: Mathematics and Sign Language

Mathematics is a fundamental subject in early education, and the development of mathematical skills is an important goal for preschool and first-grade students. However, mathematics can be a challenging subject for many students, particularly those with diverse learning needs (Schulte and Stevens, 2015). GBL has been found to be an effective way to promote the development of mathematical skills in young children (Cohrssen and Niklas, 2019). Tangible games have been shown to be particularly effective to this extent, as they offer opportunities for physical manipulation and interaction able to foster a deeper understanding of core mathematical concepts (Pires et al., 2019).

Language learning is one of the areas that is worked on in early education and its teaching and learning can be facilitated by GBL (Meyer, 2013). Most specifically, sign language implies the need for visual learning strategies – usually implemented in the classroom through images and pictures (Sousa et al., 2022) – that can be supported by the characteristics of both digital and analogue games as media. Moreover, both sign language teachers and special education teachers tend to acknowledge the pedagogical potential of games in the learning process, transversally to different curriculum subjects (Sousa et al., 2022).

1.3 Games and Inclusive Education

Inclusive education follows the social model which considers that disability only happens when there is a mismatch between the needs of the person and the environment that encompasses the person (Sousa et al., 2022). Therefore, it recognizes the diversity of students' needs and preferences and provides personalized learning experiences (Salgarayeva et al., 2021; Subban et al., 2022), similar to what GBL is able to do. Inclusive education also promotes social interaction and collaboration among students with different backgrounds and abilities, which can enhance their learning and social skills. Several authors also mention that inclusive education in the early years (preschool and kindergarten) is more effective than in the subsequent years of education (Bergen, 2003; Mallia-Milanes, 2017; Szumski, Smogorzewska and Grygiel, 2022).

GBL has been identified as a potential approach to the promotion of inclusive education, as it provides a fun and engaging way for students with diverse learning needs to access and interact with educational content (Sousa et al., 2022).

To implement a game-based strategy in an inclusive classroom it is crucial to ensure that the game is accessible. Accessibility in games relates to the design of the game being adequate to the needs of its players, whether they are related to vision, hearing, motor skills, cognition, or any other (Cezarotto et al., 2022). In the specific case of the Deaf community, creating an accessible and inclusive game implies the integration of sign language videos, witch should take in consideration five dimensions: (1) cultural, where the participation of someone from the community is key for the game to be welcomed in the community; (2) educational, it is necessary that the sign interpreter understands the concept of what is translating; (3) psychosocial, the DHH person must trust on what is being translated; (4) semantic, sign languages have different semantics in relation to the spoken language, as such it might be hard to find the corresponding signs to translate, when that happens the interpreter might resort to fingerspelling; and (5) multimodal, sign language is usually done with the combination of facial expressions and signs and has its one grammatical structure, as such it could be hard to have an accurate translation of the material if not by someone 'real' instead of virtual characters, since the accuracy of the hand movements, location, and orientation, as well as the use of facial expressions, are crucial for conveying the message (Westin et al., 2022).

Considering the above-explored theoretical framework, based on the concepts of GBL, tangible games, and inclusive education, the present study aims to contribute to this body of research by investigating the potential of a tangible game (GIM) to support the teaching of math and Portuguese sign language to preschool and first-grade children.

2. Materials and Methods

2.1 The Tangible Game: GIM

2.1.1 General concept

GIM combines physical cards with digital videos that run on an interface specifically designed for this game. The current version of the game is composed of two sets of cards and respective animations: the drawing of numbers between zero and nine; ten actions related to localization terms (e.g., above, below, in front of, behind). As an Inclusive Math Glossary, it also includes videos where concepts, characters, and objects are identified through images, words, and sign language.

The concept of the game is based on the classic memory game in which the cards are placed face down and the player turns over two cards in turn to find the equal pair. If the cards turned over are the same, the pair is collected, if they are different, they are turned over again in the same place; the player who gets the most pairs right wins.

2.1.2 Content and interaction

The GIM version features matching cards that are related, but not identical. For example, in the set of cards related to localization terms, one card depicts an animal without any props, while the other shows the same animal in a position that illustrates the localization concept in question (e.g., a snake under a rug, or a mouse inside a fridge). Similarly, in the set dedicated to numbers, one card shows a representation of a number with human-like characteristics such as eyes and feet, while its pair displays the traditional representation of the number, with dashed lines and arrows indicating the "correct" way to draw it.

This logic of distinct pairs aims to encourage children at kindergarten age to create narratives and stories by using the game's elements. For instance, the isolated mouse depicted on one card is the same one that appears inside the fridge on another card. This design choice prompts children to ask questions and create stories around the images, such as "What is that funny mouse doing inside the fridge? How did it get there?" This approach helps foster children's creativity and imagination while also promoting their cognitive development.

Although these cards have stand-alone value, they are supposed to be complemented by short animations in video format that illustrate the concepts suggested in the card with props (e.g., a mouse inside the fridge). In the case of the localization terms set, there is a basic narrative that is based on the universal "hide-and-seek game" where the different animals represented in the cards and animations are hidden somewhere in the different rooms of a house. The video begins with a question mark that invites the child to anticipate the position of the animal in a static picture representing a room of the house that, after a few seconds, comes "to life" with movements of the hidden animal that eventually comes out of its hiding place revealing itself to the child.

In the numbers set, the animated video starts with a dot that will "draw" the number according to the direction indicated in the respective card and that, after reinforcement of the drawing direction by animated arrows, gives place to the fun "character number" represented in the card that completes the pair.

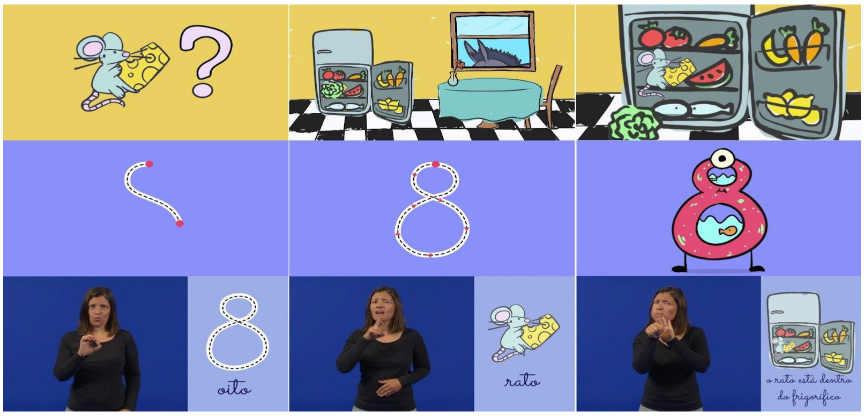

Figure 1: Video frames. Top row - sequence from the "inside" position; middle row - drawing of the number 8; bottom row (glossary) - number 8, partial sequence for "mouse is inside the fridge" (missing the frames of "inside" and "fridge")

The animations are then associated with one of the cards in the pair, either animation of objects and characters (localization set) or drawing of numbers (numbers set), with the three dimensions of the inclusive glossary mentioned earlier (image, word, and sign language) related to the other card.

2.1.3 Interface

The videos mentioned before run on the interface that completes this game and is activated by inserting the cards into an open slot on the side. It is a triangular pyramid-shaped object, designed to be reproduced at low cost with laser cutting and 3D printing machines that are commonly found in so-called FabLabs. It integrates a screen, a camera, and a Raspberry Pi board that allows the playback of the respective video by reading the QR code engraved on one side of the cards. The project's output is to make the cutting plans, assemblies, codes, and video content available for free, to allow the reproduction of this game anywhere with access to the technologies and materials mentioned. In the implemented version, we chose to produce the cards and interface structure in 3mm MDF, for its low cost, resistance, and ease of machining with laser technology.

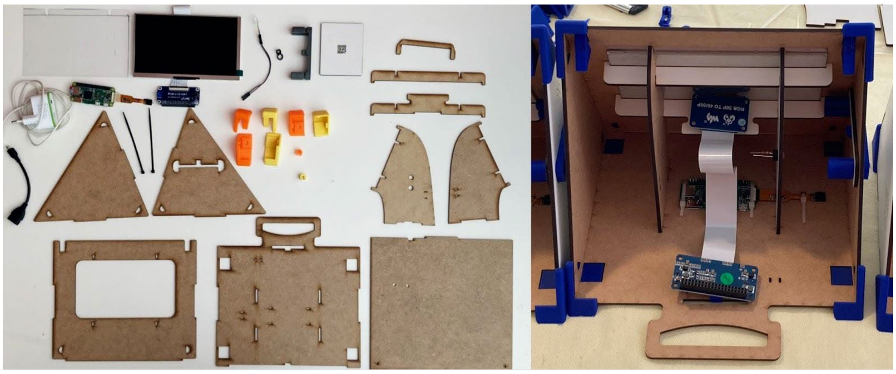

Figure 2: Pre-assembled interface components (left); inside view of the partially assembled interface (right)

2.1.4 Process

GIM's development process involved a multidisciplinary team, including a mathematician, an interaction designer, a psychologist, and a teacher who specialized in teaching the DHH. The team collaborated with a focus group of preschool and primary school teachers who specialized in teaching the DHH to validate the relevance of the content and the playful approach.

Following a sequential logic of intervention in the game development, the team developed the concept, narrative, interaction format, and content description. They also produced the visual proposal, including the design of characters, frames, and animation. A prototype of the interface was produced, and the feasibility of laser cutting and engraving was tested to produce the cards.

After validating the contents and illustrations with the focus group, the team moved on to the final production, which included the filming of sign language videos. A Deaf sign language teacher and a sign language interpreter joined the team to ensure the clarity of the sign language videos and refine the written sentences accompanying the glossary to avoid terms or grammatical structures that may cause confusion for DHH children.

Figure 3: Finished interface and cards (left); the partial set of cards in the finishing stage (right)

2.2 Participants

The study was conducted with the participation of teachers and students. Starting with teachers (*N* = 7), it is possible to divide them into two groups, preschool (*N* = 5) and first grade (*N* = 2) from three different schools. Additionally, of the teachers from preschool, there were teachers who did not know Portuguese Sign Language (*Língua Gestual Portuguesa*; LGP) (*N* = 3), who knew LGP fluently (*N* = 1), and a teacher of LGP (*N* = 1). The first-grade teachers did not know LGP.

With regard to students (*N* = 120), of which 75 were identified as males (62.50%) and 44 as females (36.67%), and their ages varied between 3 and 8 years old (*M* = 5.61; *SD* = 0.78), 101 were hearing students (84.17%) and 19 were DHH (15.83%) with no deaf parent (*N* = 0). Additionally, 12 (10%) had other special educational needs like autism (*N* = 6), functional diversity (*N* = 3), hyperactivity disorder, and attention deficit (*N* = 2), or were dependent on a Percutaneous Endoscopic Gastrostomy (PEG) to their nutritional needs (*N* = 1). It is also possible to divide them into different schools, school 1 (*N* = 9), school 2 (*N* = 9), and school 3 (*N* = 102), and different school years, preschool (*N* = 58) and first grade (*N* = 62). Schools 1 and 3 are mainstream schools whereas school 2 is a reference school.

2.3 Data Collection Instruments

To know the results from the implementation of GIM in their classrooms it was necessary to have four different interviews with the teachers (one with the teacher from school 1, two with each teacher from school 2, and one with all teachers from school 3) and to create two distinct documents that were sent to each teacher, one where they could characterize the students that participated in the study and other where they could annotate the date of the sessions, class, number of participants, and make observations that they considered relevant.

Moreover, for the interviews, it was used a semi-structured script that contained 18 questions to ascertain their opinions about the implementation of GIM (how it was used, the interaction that the children had with it), its advantages and disadvantages, the impact in the classroom and the learning process, as well as its potential improvements, in the inclusion of DHH children in education and in raising awareness in hearing children.

2.4 Procedure

Following the development process of GIM described above, we proceeded to conduct an empirical study with the support of LGP and special education teachers in three partner schools. For each school and its respective teacher, we provided detailed information on the use of the game and the data collection instruments. The game testing period was carried out between January and April 2022 in all three schools. A total of 54 test sessions were conducted during this period, with the participation of the individuals described in section 2.2.

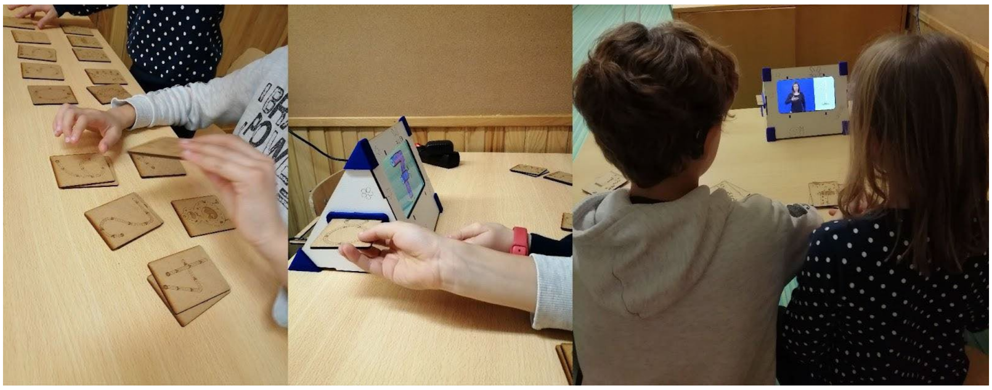

Figure 4: Children playing with GIM: 1) card pair identification; 2) card insertion in the interface; 3) video watching

All collaborating teachers were interviewed after this period in order to explore their experience of implementing GIM, with a focus on the above-defined research aim. The interviews were held via Zoom, and, with the explicit permission of the participants, recorded. They were then transcribed and coded using NVIVO software, where each sentence was considered a unit of analysis. The code used is listed below.

- General observations about the game
  - Game usage mode
  - Advantages of this pedagogical resource
  - Disadvantages of this pedagogical resource
  - Potential improvement points
  - Potential accessibility problems/lack of suitability for the target audience
  - Technical difficulties
- Game audience
  - Deaf children
  - Hearing children
- Children's attitude towards the game
  - Positive attitudes
  - Negative attitudes
- Identified needs
  - Creation of own resources
  - Additional existing resources
- LGP related aspect
  - Specificities of deaf children educational process
  - Deaf representativeness
  - Constraints to the implementation of the game
- Game Impact
  - Impacts on learning acquisition
  - Impacts on engagement
- Game Role on Inclusion and Awareness
- General positive attitudes toward the project

As mentioned above the analysis of the transcriptions was done using the NVIVO software, version 12, with 25.00% (one randomly selected focus group transcription) of the transcriptions being analyzed by two coders. The Inter Coder Reliability (ICR) was considered acceptable, with an average agreement rate between the two coders of 86.23%.

3. Results

Throughout the four interviews, the participants, when talking about the implementation of the game in the classroom and about the GIM project, addressed several topics, some more than others. The most discussed topics were the following: *Potential improvement points* (N = 81; 14.54%), mentioned in four out of the four interviews analyzed; *Game usage mode* (N = 75; 13.46%), mentioned in four out of the four interviews analyzed; *Advantages of this pedagogical resource* (N = 56; 10.05%), mentioned in four out of the four interviews analyzed;

Specificities of deaf educational process (*N* = 49; 8.80%), mentioned in three out of the four interviews analyzed; and *Disadvantages of this pedagogical resource* (*N* = 45; 8.08%), mentioned in four out of the four interviews analyzed. On the other hand, the topics that were least addressed throughout the four interviews were: *Hearing children* (*N* = 2; 0.29%), mentioned in two out of the four interviews analyzed; *Impacts on engagement* (*N* = 6; 1.08%), mentioned in one out of the four interviews analyzed; *Additional existing resources* (*N* = 7; 1.26%), mentioned in two out of the four interviews analyzed; *Constraints to the implementation of the game* (*N* = 8; 1.44%), mentioned in two out of the four interviews analyzed. These and other results are detailed in Table 1.

Table 1: Content analysis of the interviews' most coded nodes (557 coded units; 4 coded items)

Codes	Number of coded units *N* (%)	Number of coded items *N* (%)
1. General observations about the game	**311 (55.83)**	**4 (100.00)**
1.1. Game usage mode	75 (13.46)	4 (100.00)
1.2. Advantages of this pedagogical resource	56 (10.05)	4 (100.00)
1.3. Disadvantages of this pedagogical resource	45 (8.08)	4 (100.00)
1.4. Potential improvement points	81 (14.54)	4 (100.00)
1.4.1. Audience age	25 (4.49)	2 (50.00)
1.5. Potential accessibility problems/lack of suitability for the target audience	12 (2.15)	3 (75.00)
1.6. Technical difficulties	17 (3.05)	4 (100.00)
2. Game audience	**12 (2.15)**	**3 (75.00)**
2.1. Deaf children	10 (1.80)	3 (75.00)
2.2. Hearing children	2 (0.36)	2 (50.00)
3. Children's attitude towards the game	**52 (9.33)**	**4 (100.00)**
3.1. Positive attitudes	34 (6.10)	4 (100.00)
3.2. Negative attitudes	18 (3.23)	2 (50.00)
4. Identified needs	**20 (3.59)**	**4 (100.00)**
4.1. Creation of own resources	13 (2.33)	2 (50.00)
4.2. Additional existing resources	7 (1.26)	2 (50.00)
5. LGP-related aspect	**74 (13.29)**	**3 (75.00)**
5.1. Specificities of deaf children educational process	49 (8.80)	3 (75.00)
5.2. Deaf representativeness	17 (3.05)	3 (75.00)
5.3. Constraints to the implementation of the game	8 (1.44)	2 (50.00)
6. Game Impact	**34 (6.10)**	**4 (100.00)**
6.1. Impacts on learning acquisition	26 (4.67)	4 (100.00)
6.2. Impacts on engagement	6 (1.08)	1 (25.00)
7. Game role on inclusion and awareness	**38 (6.82)**	**4 (100.00)**
8. General positive attitudes toward the project	**16 (2.87)**	**3 (75.00)**

For further analysis, quantitative data from the content analysis was used to compare the perceptions of teachers of deaf and hearing children. Overall, data indicates the most expressive results for the sample of deaf children for all the analyzed categories, except: the *negative attitudes towards the game*, which were higher in the hearing children (*N* = 14; 77.78%), than in the deaf children (*N* = 4; 22.22); and the *impacts on engagement*, that were also only registered in the hearing group (*N* = 7; 100.00%). All the subcategories associated with LGP-related aspects were only registered in the sample of deaf children, which includes: *specificities of deaf children's* *educational process* (*N* = 49); *deaf representativeness* (*N* = 17); and *constraints to the implementation of the game* (*N* = 8). Full results are presented in Table 2.

Table 2: Content analysis of the interviews' most coded nodes, by group (557 coded units; 4 coded items)

Codes	Deaf children *N* (%)	Hearing children *N* (%)
1. General observations about the game	**203 (65.27)**	**108 (34.73)**
1.1. Game usage mode	61 (61.00)	39 (39.00)
1.2. Advantages of this pedagogical resource	39 (69.64)	17 (30.36)
1.3. Disadvantages of this pedagogical resource	36 (80.00)	9 (20.00)
1.4. Potential improvement points	49 (60.49)	32 (39.51)
1.4.1. Audience age		
1.5. Potential accessibility problems/lack of suitability for the target audience	6 (50.00)	6 (50.00)
1.6. Technical difficulties	12 (70.59)	5 (29.41)
2. Game audience	**11 (91.67)**	**1 (8.33)**
2.1. Deaf children	10 (100.00)	0 (0.00)
2.2. Hearing children	1 (50.00)	1 (50.00)
3. Children's attitude towards the game	**24 (46.15)**	**28 (53.85)**
3.1. Positive attitudes	20 (50.82)	14 (41.18)
3.2. Negative attitudes	4 (22.22)	14 (77.78)
4. Identified needs	**16 (80.00)**	**4 (20.00)**
4.1. Creation of own resources	13 (100.00)	0 (0.00)
4.2. Additional existing resources	3 (42.86)	4 (57.14)
5. LGP-related aspect	**74 (100.00)**	**0 (0.00)**
5.1. Specificities of deaf children educational process	49 (100.00)	0 (0.00)
5.2. Deaf representativeness	17 (100.00)	0 (0.00)
5.3. Constraints to the implementation of the game	8 (100.00)	0 (0.00)
6. Game Impact	**20 (58.82)**	**14 (41.18)**
6.1. Impacts on learning acquisition	20 (74.07)	7 (25.93)
6.2. Impacts on engagement	0 (0.00)	7 (100.00)
7. Game role on inclusion and awareness	**22 (57.89)**	**16 (42.11)**
8. General positive attitudes toward the project	**16 (100.00)**	**0 (0.00)**

By analyzing the Pearson correlations, calculated through the similarity of the coded words by node and case, a dendrogram was elaborated, as presented in Figure 5. Through the mapping of the obtained correlations, it is possible to highlight the existence of several statistically significant correlations:

- The specificities of deaf children's educational process and the game audience (r = 0.98), as well as with LGP-related aspects (r = 0.95);
- The issues of deaf representativeness and the specificities of deaf children's educational process (r = 0.98);
- The identified needs in terms of additional existing resources and the audience's age (r = 0.97);

- The general positive attitudes towards the project and LGP-related aspects (*r* = 0.97), as well as with the specificities of deaf children's educational process (*r* = 0.95), and deaf representativeness (*r* = 0.94).

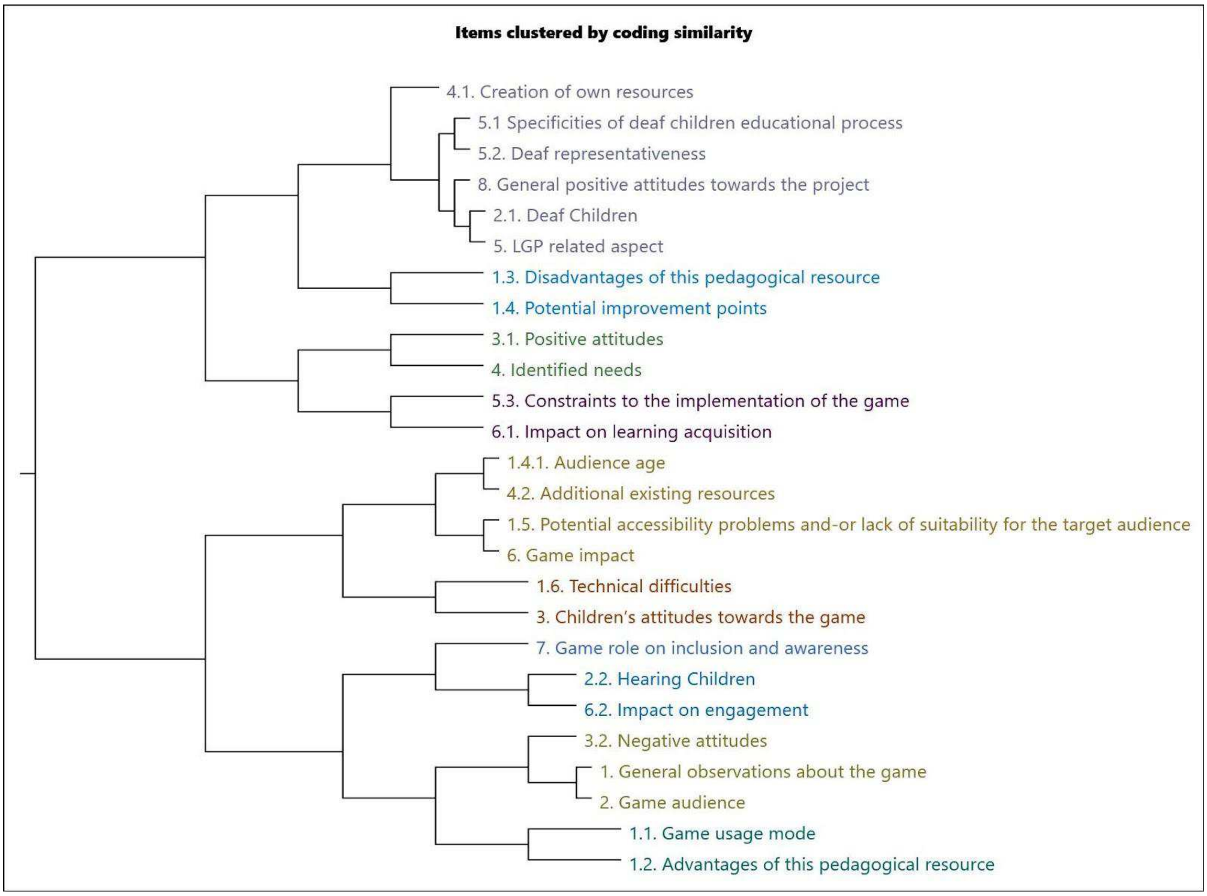

Figure 5: Dendrogram of Pearson correlations, by the similarity of the material coded in each case and node (557 coded units; 4 coded items)

4. Discussion

This study aimed to explore the potential of GIM, a tangible game, to support the teaching of mathematics and LGP to preschool and first-grade children. This study focused on analyzing the role of the game in the context of DHH and hearing children, emphasizing knowledge acquisition, involvement in the teaching-learning process, awareness of difference, and the principles of inclusive education.

The findings of this study indicated that GIM has the potential to support the teaching of mathematics and LGP to preschool and first-grade children. The tangible nature of the game made it easy for children to engage with mathematical concepts and LGP. The game provided a unique and interactive learning experience for the children that seemed to be aligned with the specificities of DHH children's educational process and needs.

GIM was found to be effective in promoting knowledge acquisition and involvement in the teaching-learning process. The game allowed children to engage with mathematical concepts and LGP in a fun and interactive way. Although these conclusions can be extended to DHH and hearing children, the impact on the acquisition of knowledge seems to be more salient in the first group. On the other hand, the game demonstrated a similar impact on the awareness of difference and the promotion of inclusion in both populations.

This approach was found to promote DHH representation and inclusivity by incorporating pedagogical resources such as sign language and a DHH adult in their instructional videos. This approach has been shown to be particularly beneficial for DHH children, as it enhances their educational experience in a way that is unique to their needs.

In conclusion, this study has shown that GIM has the potential to support the teaching of mathematics and LGP to preschool and first-grade children, particularly in the context of inclusive education. The tangible nature of the game made it easy for children to engage with mathematical concepts and LGP, leading to greater knowledge acquisition and involvement in the teaching-learning process. Furthermore, the game promoted awareness of difference and the principles of inclusive education, making it an effective tool for promoting social inclusion and understanding.

4.1 Limitations and Future Directions

While this study has demonstrated the potential of GIM to support the teaching of mathematics and LGP to preschool and first-grade children in the context of inclusive education, there are several limitations to this research. Firstly, the sample size was relatively small, and the study was conducted in a specific cultural and linguistic context. Therefore, caution must be taken when generalizing the findings to other contexts, namely considering the different national legal frameworks of inclusive and deaf education. Additionally, the study did not assess the impact of GIM on learning outcomes in a direct manner, due to pandemic restrictions, but through the participating teachers. Further research is also needed to investigate the sustained effects of using the game in the classroom, through exploring its long-term impacts.

Future research in this area should focus on addressing the limitations of this study and exploring the potential of GIM in different contexts. Firstly, larger sample sizes and multi-site studies should be conducted to investigate the generalizability of the findings. Secondly, longitudinal studies should be carried out to assess the long-term impact of GIM on learning outcomes. Finally, future studies should focus on assessing specific learning outcomes achieved by using the game and exploring the potential of GIM to support the teaching of other subjects in addition to mathematics and LGP. Additionally, future studies could explore the use of GIM in other age groups or for children with different abilities, to further explore the potential of the game as an inclusive educational tool.

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