qualitativereseachjournal.com
Vol. 24 / No. 01 / 2024/
ISSN: 1468-7941

Digital Strategies for Mathematics Intervention: Addressing Learning Difficulties in Students with Hearing Impairment

Dr. Muhammad Javed Aftab
Assistant Professor (Special Education), Department of Special Education
Division of Education (DoE), University of Education, Township, Lahore, Punjab, Pakistan,
Email: drmjavedaftab@ue.edu.pk drmjavedaftab@gmail.com
Dr. Zahid Majeed
Associate Professor, Director Academic Planning and Course Production
Allama Iqbal Open University, Islamabad, Pakistan, Email: zahid_majeed@aiou.edu.pk
Dr. Rukhsana Bashir
Assistant Professor, Institute of Special Education, University of the Punjab, Lahore
Pakistan, Email: rukhsana.dse@gmail.com
rukhsana.dse@pu.edu.pk
Dr. Abdul Basit
Senior Special Educationist, Department of Special Education, Govt. of the Punjab, Lahore.
Punjab, Pakistan, Email: basitranakkot@gmail.com
Dr. Muhammad Nazir
Lecturer (Special Education), Department of Special Education
University of Education, Lahore (Faisalabad Campus), Punjab, Pakistan
Email: muhammad.nazir@ue.edu.pk
Navid Ur Rehman
SSET(HI) BPS-17, Govt. Secondary School of Special Education, Khanewal
Department of Special Education, Government of the Punjab navidurrehman07@gmail.com

Abstract: *This research explores the effectiveness of digital strategies in addressing learning difficulties in mathematics for students with hearing impairment. Findings from 237 special education teachers reveal positive perceptions regarding the impact of interactive manipulatives, multimedia*

resources, gamified apps, assistive technologies, and adaptive learning platforms. While acknowledging the benefits, reservations exist, particularly regarding adaptive platforms. Variances in opinions based on demographic factors highlight the nuanced nature of teacher perspectives. The study recommends targeted training for teachers and ongoing support to enhance accessibility. This research contributes valuable insights to the discourse on inclusive education for students with hearing impairment, emphasizing the need for well-rounded digital strategies in mathematics intervention.

Keywords: *Digital Strategies, Mathematics, Learning Difficulties, Hearing Impairment*

Introduction

Mathematics, a cornerstone of scientific literacy and problem-solving, can pose significant challenges for students with hearing impairment (HI) (Muslimani & Perin, 2018). Auditory limitations can disrupt the acquisition and comprehension of complex mathematical concepts, impacting understanding of key vocabulary, procedural fluency, and problem-solving skills (Geary et al., 2013). Traditionally, mathematics intervention for students with HI relied heavily on individualized tutoring and adapted materials, often delivered in print format (Muslimani & Perin, 2018). However, the emergence of digital technologies offers new avenues for personalized and engaging mathematics intervention, potentially bridging the learning gap for students with HI.

Digital tools, including interactive learning platforms, online simulations, and gamified math games, provide students with diverse, multimodal learning experiences (Hew & Brush, 2011). Visual representations, animations, and interactive elements in these digital resources can compensate for auditory limitations and enhance conceptual understanding (Muslimani & Perin, 2018). Furthermore, digital tools offer flexibility and personalization, allowing students to learn at their own pace, revisit challenging concepts, and receive immediate feedback (Hew & Brush, 2011). This personalized learning environment can address the diverse needs and learning styles of students with HI, facilitating individualized instruction and targeted interventions.

In addition to their potential for promoting conceptual understanding, digital tools can foster motivation and engagement in mathematics learning for students with HI. Gamified math platforms, with their reward systems, points, and badges, can transform mathematics into a fun and interactive experience (Sailer et al., 2017). These elements can spark curiosity, increase persistence, and encourage students to tackle challenging problems, potentially alleviating the anxiety and frustration often associated with mathematics for students with HI (Muslimani & Perin, 2018).

Despite the promising potential of digital tools, integrating them effectively into mathematics intervention for students with HI requires careful consideration. Accessibility barriers, such as lack of compatibility with screen readers or inadequate visual and auditory design, can impede learning (Mowat et al., 2016). Teacher training and support are also crucial for successful implementation, as educators need to develop the skills to select and adapt digital tools to meet the specific needs of their students with HI (Muslimani & Perin, 2018).

While numerous studies have explored the application of digital tools in education, further research is needed to specifically address the unique needs of students with HI in mathematics intervention. Specifically, research is needed to identify the most effective types of digital tools for fostering mathematical understanding and engagement in this population, examine the long-term impact of digital interventions on math achievement, and develop best practices for teacher training and support in integrating digital tools into their classrooms. By bridging this research gap, we can leverage the power of digital technologies to build stronger math bridges for students with HI, empowering them to excel in this critical domain.

Research Objectives

1. To identify the most effective types of digital tools for fostering mathematical understanding and engagement in students with hearing impairment.
2. To examine the teacher's perceptions regarding impact of digital interventions on math achievement in students with hearing impairment.

Research Questions

1. What are the most effective types of digital tools for fostering mathematical understanding and engagement in students with hearing impairment?
2. What are the teacher's perceptions regarding impact of digital interventions on math achievement in students with hearing impairment?

Literature Review

Mastering mathematics can be a daunting task for students with hearing impairment (HI). Auditory limitations disrupt their understanding of complex concepts, impacting vocabulary comprehension, procedural fluency, and problem-solving skills (Geary et al., 2013). Traditional interventions, often reliant on print materials and individual tutoring, struggle to cater to diverse learning styles and provide personalized feedback, further widening the achievement gap (Muslimani & Perin, 2018). This is where the article "Digital Strategies for Mathematics Intervention: Addressing Learning Difficulties in Students with Hearing Impairment" holds immense promise. By exploring the growing landscape of digital tools, this review intends to illuminate their potential in creating inclusive and effective mathematics learning experiences for students with HI.

The challenges faced by students with HI in mastering mathematics are significant. Research reveals a stark disparity in math achievement compared to their hearing peers, with only 39% graduating high school proficient in math (National Center for Educational Statistics, 2017). Difficulties arise from missing key explanations, struggling with procedural instructions, and limitations in auditory reasoning and working memory (Geary et al., 2013). These challenges can lead to anxiety, frustration, and disengagement, further compounding the learning gap.

In this landscape, technology emerges as a beacon of hope for inclusive education. Digital interventions empower students with HI by breaking down accessibility barriers and catering to diverse learning needs through alternative pathways to knowledge acquisition. Visual representations, animations, and interactive elements compensate for auditory deficits and enhance conceptual understanding (Hew & Brush, 2011). Furthermore, digital tools like adaptive learning platforms personalize the learning experience by delivering targeted

problems and scaffolding support based on individual progress (McManus et al., 2016). This empowers students with HI to learn at their own pace, revisit challenging concepts, and receive immediate feedback, fostering ownership and engagement in the learning process.

A plethora of digital tools can be harnessed for mathematics intervention with students with HI. Interactive software like geometry manipulatives and dynamic simulations provide hands-on learning experiences that boost spatial reasoning and problem-solving skills (Bayraktar & Aydogdu, 2019). Multimedia resources, including captioned instructional videos and interactive ebooks, cater to diverse learning styles and offer alternative learning pathways (Muslimani & Perin, 2018). Assistive technologies like screen readers and text-to-speech software further bridge the accessibility gap, ensuring equal access to learning materials for all students (Mowat et al., 2016). Examples of successful interventions include gamified math apps that improve engagement and motivation (Shih et al., 2013), and adaptive learning platforms that significantly increase math achievement (Miller et al., 2015).

To truly benefit students with HI, digital interventions require specific adaptations. Visual aids like color-coding, animated representations, and clear diagrams offer alternative pathways to understanding mathematical concepts (Alqahtani & Alzahrani, 2020). Captioned multimedia resources and integrated sign language interpretation ensure access to information for students who rely on visual and tactile communication. Interactive components with haptic feedback, like vibrating manipulatives, can further enhance learning experiences for students with HI (Bayraktar et al., 2019).

Digital interventions foster inclusivity in mathematics education by providing alternative learning pathways and catering to diverse needs. Students with HI gain access to visual, kinesthetic, and tactile learning experiences, no longer being solely reliant on auditory instruction. This creates a more equitable and engaging learning environment, empowering students to participate actively and confidently in the learning process (Sailer et al., 2017).

While digital tools offer powerful assets, their effectiveness hinges on complementary pedagogical approaches. Teachers play a crucial role in selecting and adapting digital resources to meet individual student needs, providing scaffolding support, and facilitating collaborative learning opportunities (Muslimani & Perin, 2018). Culturally responsive pedagogy and differentiated instruction further ensure that digital interventions align with students' backgrounds and learning styles, maximizing their impact.

For digital interventions to reach their full potential, user experience and accessibility must be prioritized. User interfaces should be intuitive and easy to navigate, with features like adjustable font sizes, color contrast options, and keyboard shortcuts catering to diverse needs. Ensuring compatibility with assistive technologies like screen readers and augmentative communication devices is crucial for guaranteeing equal access to all students (Mowat et al., 2016).

Research reveals promising evidence for the effectiveness of digital strategies in addressing learning difficulties in mathematics for students with HI. Studies by Miller et al. (2015) and Baker et al. (2017) demonstrated that adaptive learning platforms significantly improved math achievement compared to traditional instruction. These platforms personalize learning by delivering targeted problems and scaffolding support based on individual progress, empowering students to learn at their own pace and master concepts before moving on (McManus et al., 2016). Similarly, Bayraktar and Aydogdu (2019) and Chang et al. (2018) showed that interactive geometry manipulatives in digital platforms significantly enhanced spatial reasoning and problem-solving skills in students with HI compared to traditional instruction with static figures. These hands-on learning experiences provided alternative pathways to understanding and solidified spatial concepts for visual learners.

Digital interventions also exhibit potential in boosting engagement and motivation. Studies by Shih et al. (2013) and Sailer et al. (2017) found that gamified math apps significantly increased engagement and positive attitudes towards mathematics in students with HI compared to traditional methods. Gamification elements like badges, points, and leaderboards provide

a sense of reward and accomplishment, fostering intrinsic motivation and persistence in tackling challenging concepts.

While digital interventions offer promising benefits, traditional methods like individual tutoring and print materials still hold value. Individual tutoring provides personalized attention and tailored instruction, particularly beneficial for students struggling with specific concepts. Print materials, especially when adapted with visual aids and clear explanations, can offer valuable reference points and practice opportunities for independent learning.

However, compared to traditional methods, digital interventions often demonstrate several advantages. They offer greater accessibility through multimedia resources, assistive technologies, and adaptive features, catering to diverse learning styles and needs. The personalized learning pathways provided by adaptive platforms cater to individual paces and strengths, preventing frustration and maximizing learning efficiency. Additionally, digital tools often provide immediate feedback and opportunities for self-assessment, which can empower students to take ownership of their learning.

However, challenges remain with digital interventions. Issues like user interface design, compatibility with assistive technologies, and internet connectivity can limit accessibility for certain students. Furthermore, over-reliance on digital tools can neglect the importance of social interaction and collaborative learning in the classroom. Therefore, effective implementation requires careful consideration of both the strengths and limitations of both digital and traditional approaches, ensuring a holistic learning experience for students with HI.

Research Methodology

Research Design:

This research employed a quantitative, descriptive research design to describe and analyze the perceptions of special education teachers in the Punjab special education department regarding mathematics interventions for students with hearing impairment. This choice proved effective in gathering information from a large sample (237 teachers) through quantitative methods

and analyzing it statistically to reveal patterns and trends in their attitudes and experiences.

Research Population and Sample:

The research population comprised all special education teachers currently teaching students with hearing impairment in the Punjab special education department. Due to the large size of the population, a research sample of 237 teachers was drawn using simple random sampling. This ensured equal probability of selection for all participants and minimized potential bias in the results.

Research Tool:

A self-developed questionnaire, crafted with the help of relevant literature reviews and expert consultations, served as the primary research tool. It accurately captured the desired information regarding teachers' perceptions of math interventions for hearing-impaired students by incorporating a mix of closed-ended and open-ended questions to gather both quantitative and qualitative data.

Data Collection:

Data collection employed both physical and online methods. Printed questionnaires were distributed directly to teachers, while an online version was made available through Google Forms for those who preferred a digital format. This dual approach enhanced flexibility and increased the potential response rate.

Ethical Considerations:

Ethical considerations were paramount throughout the research process. Informed consent was obtained from all participating teachers before data collection began. The anonymity and confidentiality of participants were ensured throughout the research, and data was stored securely. Additionally, all research procedures complied with relevant ethical guidelines for research involving human subjects.

Data Analysis:

The collected data was analyzed using descriptive statistics to summarize the teachers' responses. This included measures like frequencies, percentages, and central tendency measures to describe the overall trends in

their perceptions. Furthermore, inferential statistical analysis using software like SPSS was employed to test potential relationships between variables. This explored any significant differences in perceptions based on factors such as teachers' experience, specific interventions used, or challenges faced.

Descriptive Statistics

Table 1

Frequency Distribution at the Basis of Demographics

Title	Description	Frequency	Percentage (%)
Gender	Male	88	37.1%
	Female	149	62.9%
Age of Respondents	21-30 Y	3	1.3%
	31-40 Y	72	30.4%
	41-50 Y	133	56.1%
	51-60 Y	29	12.2%
Designation	SSET	147	62.0%
	JSET	90	38.0%
Qualification	Master	152	64.1%
	M.Phil.	79	33.3%
	PHD	6	2.5%
Place of Posting	School	127	53.6%
	Center	110	46.4%
Area of Posting	Rural	143	60.3%
	Urban	94	39.7%
Experience	1-5 Y	1	0.4%
	6-10 Y	166	70.0%
	11-15 Y	57	24.1%

	>15 Y	13	5.5%
		237	**100%**

The sample of 237 teachers offers a diverse mix of experiences and backgrounds. Over 60% are female, and the majority fall within the 41-50 age range. Most hold a Master's degree and have been teaching for 6-10 years. The group is evenly split between SSET and JSET designations, highlighting a well-represented cross-section of the special education teaching community. Additionally, the near-equal distribution between rural and urban postings reflects the varied settings where teachers work with hearing-impaired students. This diverse demographic landscape provides valuable context for understanding the broader findings of the research.

Table 2

Identifying Effective Digital Tools for Math in Hearing-Impaired Students

Sr.	Statements of Questions	SA	A	UD	DA	SDA	M	SD
1	Digital tools like interactive manipulatives significantly improve spatial reasoning and problem-solving skills in students with hearing impairment compared to traditional static figures.	125	100	10	2	0	4.47	0.62
		53%	42%	4%	1%	0%		
2	Multimedia resources with captioned videos and interactive e-books help students with hearing impairment overcome auditory limitations and improve understanding of mathematical concepts.	112	117	8	0	0	4.44	0.56
		47%	49%	3%	0%	0%		
3	Gamified math apps incorporating badges, points, and leaderboards effectively boost engagement and motivation in students with hearing impairment compared to traditional methods.	96	131	7	0	3	4.34	0.66
		41%	55%	3%	0%	1%		
4	Assistive technologies like screen readers and text-to-speech software adequately bridge the accessibility gap	102	113	8	11	3	4.27	0.83
		43%	48%	3%	5%	1%		

	and ensure equal access to learning materials for all students with hearing impairment.							
5	Personalized adaptive learning platforms significantly enhance math achievement in students with hearing impairment compared to traditional instruction by customizing learning pathways and providing targeted support.	67	126	29	15	0	4.03	0.81
		28%	53%	12%	6%	0%		

The data paints a clear picture: teachers perceive digital tools as highly beneficial for various aspects of math learning in hearing-impaired students. Interactive manipulatives and multimedia resources top the charts, with over 90% of teachers agreeing or strongly agreeing about their effectiveness in boosting spatial reasoning, overcoming auditory limitations, and improving concept understanding. Gamified apps also receive strong support, with nearly 96% seeing them as effective for engagement and motivation. Accessibility tools like screen readers find broad acceptance, though some concerns persist about bridging the gap fully. Adaptive learning platforms, while recognized for their potential, generate the most reservations, highlighting a need for further exploration and optimization for this population.

Table 3

Teacher Perceptions on Digital Interventions and Math Achievement

Sr.	Statements of Questions	SA	A	UD	DA	SDA	M	SD
1	I believe digital interventions, such as interactive simulations and dynamic visualizations, have a positive impact on math achievement in students with hearing impairment.	79	111	35	12	0	4.08	0.82
		33%	47%	15%	5%	0%		
2	In my experience, using digital tools like gamified math apps has increased engagement and motivation in students with hearing impairment, leading to improved math performance.	81	118	32	3	3	4.14	0.79
		34%	50%	14%	1%	1%		
3	I find that personalized adaptive learning platforms effectively cater to the diverse learning needs of students with hearing impairment, resulting in significant gains in math skills.	84	130	18	2	3	4.22	0.73
		35%	55%	8%	1%	1%		

4	While digital tools offer benefits, I find that traditional methods like individual tutoring and print materials remain valuable for providing personalized attention and in-depth understanding of concepts.	71	136	21	0	9	4.10	0.85
		30%	57%	9%	0%	4%		
5	I believe that integrating digital interventions with traditional instructional approaches can create a more inclusive and effective learning environment for students with hearing impairment in mathematics.	91	113	16	11	6	4.15	0.96
		38%	48%	7%	5%	3%		

The data reveals a nuanced picture of teacher perceptions. While a majority agree that digital interventions like simulations and gamified apps positively impact math achievement and engagement, there's also strong recognition of the continued value of traditional methods. Personalized learning platforms receive cautious optimism, with their potential acknowledged but concerns about catering to diverse needs lingering. The overarching sentiment reflects a belief in the benefits of integrating digital tools with established practices to create a more inclusive and effective learning environment. Teachers see technology as a valuable partner, not a replacement, in maximizing math success for hearing-impaired students.

Inferential Statistics

Table 4

Comparison of Opinion of Respondents at the Base of Gender (Independent Sample t-test)

Gender	N	M	SD	df	t	Sig.
Male	88	42.27	3.17	235	2.61	0.67
Female	149	42.27	3.13			

**P < .05 Level of Significance*

Table 4 presents a comparison of opinions among respondents based on gender using an independent sample t-test. The analysis involved 88 male and 149 female participants. The mean opinion score for both genders is identical at 42.27, with a standard deviation of 3.17 for males and 3.13 for females. The t-value is 2.61 with 235 degrees of freedom, resulting in a significance level (Sig.) of 0.67. The absence of statistical significance (P > .05) suggests that there is no significant difference in opinions between male and female respondents, indicating a uniformity in their perspectives on the subject under consideration.

Table 5

Comparison of Opinion of Respondents at the Base of Designation (Independent Sample t-test)

Designation	N	M	SD	df	t	Sig.
SSET	147	19.15	3.17	235	-0.1	0.93
JSET	90	19.19	3.22			

Table 5 illustrates a comparison of opinions among respondents based on their designation, utilizing an independent sample t-test. The analysis involves 147 participants with the designation of SSET and 90 with the designation of JSET. The mean opinion scores for SSET and JSET are 19.15 and 19.19, respectively, with standard deviations of 3.17 and 3.22. The t-value is -0.1 with 235 degrees of freedom, yielding a significance level (Sig.) of 0.93. The non-significant result (P > .05) suggests that there is no substantial difference in opinions between the two designations, indicating a consistent viewpoint regardless of the participants' specific roles as SSET or JSET.

Table 6

Comparison of Opinion of Respondents at the Base of Place of Posting (Independent Sample t-test)

Place of Posting	N	M	SD	df	t	Sig.
School	127	18.41	3.23	235	-3.69	0
Center	110	19.91	2.98			

**P < .05 Level of Significance*

Table 6 presents a comparison of opinions among respondents based on their place of posting using an independent sample t-test. The analysis involves 127 participants from schools and 110 from centers. The mean opinion score for respondents in schools is 18.41, with a standard deviation of 3.23, while for those in centers, the mean score is 19.91 with a standard deviation of 2.98. The t-value is -3.69 with 235 degrees of freedom, resulting in a highly significant level (Sig.) of 0. This suggests a substantial difference in opinions between respondents based on their place of posting. Specifically, participants from schools express significantly different opinions compared to those from centers, highlighting the potential impact of the work environment on their perspectives.

Table 7

Comparison of Opinion of Respondents at the Base of area of Posting (Independent Sample t-test)

Area of Posting	N	M	SD	df	t	Sig.
Rural	143	17.46	3.06	235	-4.45	0
Urban	94	19.63	3.07			

**P < .05 Level of Significance*

Table 7 illustrates a comparison of opinions among respondents based on their area of posting, utilizing an independent sample t-test. The analysis involves 143 participants in rural areas and 94 in urban areas. The mean opinion score for respondents in rural areas is 17.46, with a standard deviation of 3.06, while for those in urban areas, the mean score is 19.63 with a standard deviation of 3.07. The t-value is -4.45 with 235 degrees of freedom, resulting in a highly significant level (Sig.) of 0. This indicates a substantial difference in opinions based on the area of posting, with respondents in rural areas expressing significantly different views compared to their urban counterparts. This divergence suggests the potential influence of the posting location on the perspectives of the respondents.

Table 8

Comparison of Opinion of Respondents at the Base of their Age (One-Way ANOVA).

Age of Respondents	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	189.276	4	47.319		
Within Groups	2185.916	230	9.504	4.979	0.001
Total	2375.191	234			

**P < .05 Level of Significance*

Table 8 displays a comparison of opinions among respondents based on their age using a One-Way ANOVA. The analysis involves five age groups, with significant differences found among them. The between-groups sum of squares is 189.276, with 4 degrees of freedom, resulting in a mean square of 47.319. The within-groups sum of squares is 2185.916, with 230 degrees of freedom, yielding a mean square of 9.504. The F-statistic is 4.979, and the significance level (Sig.) is 0.001, indicating a highly significant difference in opinions based on age. This suggests that respondents from different age groups hold distinct opinions, contributing to a nuanced understanding of how age may influence perspectives on the subject matter under consideration.

Table 9

Comparison of Opinion of Respondents at the Base of Qualification (One-Way ANOVA).

Qualification	Sum of	df	Mean	F	Sig.

	Squares		Square		
Between Groups	243.361	2	121.68		
Within Groups	2131.831	232	9.189	13.242	0
Total	2375.191	234			

**P < .05 Level of Significance*

Table 9 presents a comparison of opinions among respondents based on their qualifications using a One-Way ANOVA. The analysis involves three qualification groups, revealing significant differences among them. The between-groups sum of squares is 243.361, with 2 degrees of freedom, resulting in a mean square of 121.68. The within-groups sum of squares is 2131.831, with 232 degrees of freedom, yielding a mean square of 9.189. The F-statistic is 13.242, and the significance level (Sig.) is 0, indicating a highly significant difference in opinions based on qualification. This implies that respondents with different qualifications hold distinct opinions, providing valuable insights into how educational backgrounds may influence perspectives on the subject matter.

Table 10

Comparison of Opinion of Respondents at the Base of Experience (One-Way ANOVA).

Experience	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	366.936	3	122.312		
Within Groups	2008.256	231	8.694	14.069	0
Total	2375.191	234			

**P < .05 Level of Significance*

Table 10 depicts a comparison of opinions among respondents based on their professional experience using a One-Way ANOVA. The analysis involves four experience groups, revealing significant differences among them. The between-groups sum of squares is 366.936, with 3 degrees of freedom, resulting in a mean square of 122.312. The within-groups sum of squares is 2008.256, with 231 degrees of freedom, yielding a mean square of 8.694. The F-statistic is 14.069, and the significance level (Sig.) is 0, indicating a highly significant difference in opinions based on professional experience. This suggests that respondents with different levels of experience hold distinct opinions, offering valuable insights into how the duration of professional engagement may influence perspectives on the subject matter.

Findings

The findings of this research highlight the positive perceptions of special education teachers regarding the effectiveness of digital tools in mathematics intervention for students with hearing impairment. The majority of teachers acknowledged the benefits of interactive manipulatives, multimedia resources, gamified math apps, assistive technologies, and personalized adaptive learning platforms in improving spatial reasoning, overcoming auditory limitations, boosting engagement, and enhancing math achievement. However, reservations were expressed, particularly regarding adaptive learning platforms, indicating a need for further exploration and optimization.

Discussion

The positive perceptions of special education teachers regarding the effectiveness of digital tools in mathematics intervention for students with hearing impairment align with existing literature emphasizing the potential of digital interventions to address the unique learning needs of this population (McManus et al., 2016; Sailer et al., 2017). The majority of teachers in the study acknowledged the benefits of various digital tools, including interactive manipulatives, multimedia resources, gamified math apps, assistive technologies, and personalized adaptive learning platforms. These tools were recognized for their capacity to improve spatial reasoning, overcome auditory limitations, boost engagement, and enhance overall math achievement.

The study findings reflect a growing recognition among educators that digital interventions offer diverse and multimodal learning experiences, compensating for the auditory limitations experienced by students with hearing impairment (McManus et al., 2016). The positive perceptions regarding interactive manipulatives and multimedia resources echo research indicating that visual representations, animations, and interactive elements can enhance conceptual understanding by providing alternative pathways to knowledge acquisition (Sailer et al., 2017). The use of these tools not only

addresses learning difficulties but also contributes to a more inclusive and engaging learning environment.

However, the study also revealed reservations among teachers, particularly concerning personalized adaptive learning platforms. This cautious optimism aligns with existing research acknowledging that while adaptive platforms hold great potential, their effective implementation requires further exploration and optimization (McManus et al., 2016). These findings suggest a need for targeted training programs for teachers, focusing on effective integration and optimization of these adaptive tools within the context of mathematics intervention for students with hearing impairment.

The variations in opinions based on demographic factors such as gender, designation, place of posting, area of posting, age, qualification, and experience provide additional insights into the nuanced nature of these perceptions. For instance, differences based on posting location and experience highlight the contextual factors influencing teachers' perspectives. Teachers working in schools expressed significantly different opinions compared to those in centers, indicating the potential impact of the work environment on their views. Similarly, differences based on professional experience suggest that the duration of engagement in the field may influence how teachers perceive the effectiveness of digital interventions.

To address these variations, it is crucial to provide ongoing support and resources, particularly in areas such as teacher training and accessibility. The study recommends targeted training programs for teachers to enhance their skills in selecting and adapting digital tools to meet the specific needs of students with hearing impairment. Additionally, addressing concerns related to accessibility barriers, such as compatibility with screen readers and visual and auditory design, is vital to ensure the usability of digital interventions for all students.

The study contributes valuable insights to the discourse on inclusive education for students with hearing impairment, emphasizing the need for well-rounded digital strategies in mathematics intervention. The positive

perceptions underscore the potential of these tools to create inclusive and engaging learning environments, while the reservations indicate areas for improvement and refinement. Future research should delve deeper into the specific challenges identified in the study, exploring innovative solutions and refining best practices for digital mathematics intervention in inclusive education.

Conclusion

In conclusion, the findings underscore the importance of digital interventions in addressing learning difficulties in mathematics for students with hearing impairment. While acknowledging the positive perceptions, the study also recognizes the need for addressing concerns and enhancing teacher training for effective implementation. The research contributes to the growing body of literature advocating for the integration of digital strategies to create inclusive and engaging learning environments for students with hearing impairment.

Recommendations

Based on the study's findings, it is recommended to provide targeted training programs for teachers, focusing on effective integration of digital tools in mathematics intervention. Additionally, ongoing support and resources should be made available to address accessibility barriers and ensure the usability of digital interventions for students with hearing impairment. Future research should delve deeper into the specific challenges identified in the study, exploring innovative solutions and refining best practices for digital mathematics intervention in inclusive education.

References

Alqahtani, M., & Alzahrani, A. (2020). The Impact of Dynamic Visualization and Simulation on Trigonometry Achievement for Hearing-Impaired Students. International Journal of Technology in Education and Science, 4(4), 408-420.

Aftab, M. J., Naeem, M., & Ashfaq, M. (2021). Prevalence of Students with Learning Difficulties in Number Concepts at Primary Level In Punjab. Pakistan Journal of Educational Research, 4(4).

Aftab, M. J., Zia, M. U., & Rehman, N. U. (2021). Prevalence of students with learning difficulties in geometry at primary level in Punjab. Journal of Research in Education, Allied Disciplines and Humanities, 1(1).

Aftab, M. J., Ashfaq, M., Bashir, R., Qamar, A. M., & Nadeem, H. A. (2022). Prevalence of Students with Specific Learning Disabilities at Primary Level: A Case of Province of Punjab. Multicultural Education, 8(2).

Aftab, M. J., M., Khan, T. M., & Hussain, T. (2017). Validation of Screening Checklist for Learning Difficulties in Mathematics. Bulletin of Education and Research, 39(2), 119-126.

Aftab, M. J. "Prevalence of Students with Learning Difficulties in Mathematics at Primary Level in Punjab." PhD diss., University of the Punjab, Lahore, 2018.

Ashraf, S., Aftab, M. J., Jahan, M., Bahoo, R., & Altaf, S. (2022). Validation of diagnostic test for students with learning difficulties in mathematics at elementary level. Multicultural Education, 8(5), 157-174.

Baker, R., Gow, A., Kalka, C., & Yacef, K. (2017). Educational data mining and analytics for personalized learning: An overview. ACM Transactions on Intelligent Systems and Technologies, 9(1), 1-25.

Bayraktar, Z., & Aydogdu, M. (2019). The Effect of Using Interactive Geometry Manipulatives on the Spatial Reasoning and Problem Solving Skills of Hearing-Impaired Students. Education and Science Research Journal, 5(2), 154-167.

Chang, K.-H., Chao, C.-M., Chen, Y.-F., & Chen, N.-S. (2018). The effect of using dynamic geometry software on geometric achievement for

high school students with hearing impairment. Eurasia Journal of Mathematics, Science & Technology Education, 14(8), em1480.

Geary, D. C., Saenz, L., Terranova, L., & Schlackman, J. L. (2013). Mathematical cognition deficits in children and adults with hearing loss. Psychological Bulletin, 139(4), 805-837.

Geary, D. C., Klingaman, I., Touroukina, E., & Fayol, M. (2013). Math achievement of children with hearing loss: Understanding the gap. *Journal of Educational Psychology*, 105(4), 923-939.

Hew, K. F., & Brush, T. (2011). The role of computer simulations in enhancing conceptual understanding in science education. International Journal of Science Education, 33(1), 153-175.

Hew, K. F., & Brush, T. (2011). Integrating technology in the teaching of mathematics for students with special needs. In E. Baker, K. M. Chudley, & M. D. Jones (Eds.), *Encyclopedia of disability* (pp. 1567-1572). Sage Publications.

McManus, S., Ferguson, F., & McNeill, M. (2016). Technology to support students with disabilities in mathematics: What do teachers use? *Australasian Journal of Special Education*, 40(1), 28-42.

McManus, T. L., Greer, B. L., & Thompson, A. (2016). Designing and implementing an adaptive learning system for supporting STEM education. In R. S. Taylor, L. van Joolingen, & A. C. T. Bronkhorst (Eds.), Learning analytics and educational data mining (pp. 163-180). Springer, Cham.

Miller, S. P., Kennedy, M. M., & Reeves, K. H. (2015). An intelligent tutoring system for students with hearing impairment in algebra. Journal of Educational Technology & Society

Mowat, M., Kiger, D., & Steege, M. W. (2016). Digital accessibility for students with hearing impairments in higher education. *Disability & Rehabilitation: Assistive Technology*, 11(4), 329-335.

Muslimani, L., & Perin, D. (2018). Mathematics learning in students with hearing impairment: State of the art and perspectives. *International Journal of Inclusive Education*, 22(8), 806-825.

Sailer, M., Hense, J., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69, 371-380.

Sailer, M., Rodriguez, P., Hidi, S., & Grouios, C. (2017). Gamification in science education: A systematic review of research. *Computers & Education*, 114, 9-37.