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Investigation on Understanding the Numeracy Capacity of Intellectual Disabled Students using Enabling Technology Tools: Augmented Reality and UI/UX

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Abstract - The population of individuals with intellectual disabilities (ID) is increasing, necessitating assistance with a wide range of daily activities. Acquiring and assessing numeracy and communication skills are critical for this demographic, requiring tools and techniques tailored to their specific needs. Effective educational tools must employ multi-modal and multi-sensory approaches to cater to diverse learning styles and incorporate assistive technological solutions. Despite the availability of numerous tools, there is a need to enhance their utility and effectiveness. This study aims to identify and refine the requirements for an innovative educational tool that employs Two-dimensional (2D) and Augmented Reality (AR) technologies. To achieve this, we conducted semi-structured interviews and surveys with teachers working with students with ID, gaining insights into the current solutions, advantages, and limitations. Additionally, we used physical props as design probes in a co-design methodology to better understand and elicit the true needs of individuals with ID. The findings from this research will inform the development of a 2D/AR tool designed to make learning mathematics more engaging and effective for individuals with ID, contributing to the advancement of inclusive education practices. Enabling Technology plays a significant role in the numeracy ability among people with ID. Generative AI and Explainable AI shall further improve learning ability in the years to come.

Keywords—Intellectually Disabled, Augmented Reality, Multimodal, User Experience, Enabling Technology.

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1. INTRODUCTION

This paper evaluates the potential benefits of proposed solutions for individuals with intellectual disabilities (ID) and their tutors. Understanding the needs of individuals with ID is crucial for designing effective tools that benefit them. Generally, parents, teachers, and individuals are key informants about these needs. However, these stakeholders may not always explicitly know or be able to express their needs. Our objective is to elicit requirements for a solution using strategic design probes to make learning mathematics an engaging process for individuals with ID. To achieve this, we collected data through semi-structured interviews and surveys with Teaching Assistants and Teachers who work with intellectually disabled students. We also employed the method of co-design, collaborating with adults with ID to gather requirements and develop a future-oriented solution.

2. LITERATURE REVIEW

Numeracy skills are essential for everyday life, but people with ID often struggle to learn them. This literature review will look at studies on these topics to give a clear picture of the current state of numeracy education for people with ID, focusing on the challenges and potential solutions to improve their numeracy skills.

2.1Maths Education for Intellectually Disabled Students

Mathematics is a core school subject in the United Kingdom and worldwide [1]. It teaches students important life skills, such as computation, money management, and quantity recognition, to help them become self-sufficient as they grow older [2]. The National Curriculum for England includes numbers, which is the most significant of the core strands in mathematics [1]. The number recognition and understanding, as well as operations and computations, are all included in mathematics. In England, schools are mandated to teach the number strand beginning in the early years and continuing through all key levels of education as they study further [2],[3] discussed the psychological therapy for intellectually disabled people, which helps improve the ability of such people.

In this study, we include early number abilities, generally referred to as 'numeracy,' as this is the term most used in research literature to describe basic number skills of the human being. In general, numeracy is the ability to manipulate numbers to apply them in real-world applications as they occur in day-to-day life. The work by [4] proposed an interactive educational game to improve the cognitive performance of ID people. In [5], the approaches for Text Rank Algorithms (TRA), the Luhn Algorithm (LA), the Lex Ranking Algorithm (LRA) and Latent Linguistic Analysis (LLA) were discussed. TRA, LA and LLA are compared for Text Mining Techniques (TMT) and Natural Language Processing (NLP) for the Usage of Intellectually Disabled Individuals, which analyzes the performance. In [6], the authors have designed a device that would monitor the patient's heartbeat and add GPS and GRS to make the lives of ID individuals easier and less reliant on enabling technology tools. The device can detect changes in a person's heart rate and send a message to the guardian advising them of the changes or providing location information in case of disappearance.

Figure 1 shows that Numeracy is more than just being able to add, subtract, multiply, and divide as basic operations. Numeracy refers to the capacity to employ mathematical knowledge and abilities to address problems and carry out daily tasks in complicated social contexts and environments.

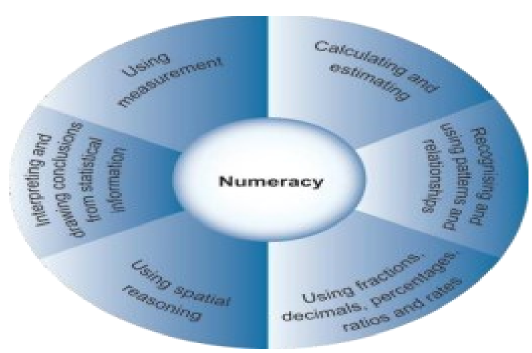

Figure1. Numeracy [7]

For a young person to possess this skill, they must be able to think, communicate quantitatively, interpret data, be spatially aware, comprehend patterns sequences, and identify circumstances in which mathematical reasoning can be used to solve issues that may arise from different situations [8], provide five explanations for why children with ID may struggle in mathematics in his day-to-day life.:

- It is possible that they are not given enough opportunities to learn during the time frame.
- There may be a greater emphasis on teaching functional mathematical abilities rather than wider, structured maths skills used in classrooms.
- Teachers may not be equipped or confident in teaching math to students with autism.
- Due to challenging behaviors and distractions during lessons, teachers may find it difficult to teach mathematics to the students.
- Teachers may find it challenging to collect knowledge and implement evidence-based teaching practices.

Furthermore, according to [9], teachers who work with children witha variety of needs require a customized approach. Still, they often have a scarcity of time or experience to change the curriculum to meet each student's requirements. As a result, students' math instruction is frequently confined to fundamental money abilities and number recognition. This is insufficient in events involving people with ID who must interact and travel by bus or train.

As per [10], students with ID aged 5 to 12 can successfully develop skills in early numeracy, arithmetic, and problem-solving as they arise in day-to-day life. Effective instructional approaches include systematic and explicit instruction with feedback and the use of a manipulative approach to meet the needs of the time. Mathematics instruction should feature well-structured, high-intensity learning sequences that are individualized and adapted to the students' achievement levels during their study. Scripted lesson plans for teaching specific skills can also be beneficial in delivering instruction with these characteristics when teaching people with ID. [11]described the AI based methods for ID.

2.2. Difficult Areas of Maths For Students With ID

2.2.1. Difficulty With Spatial Relationships (DSR)

DSR means where the objects are located with respect to other objects. The level of disability defines this aspect. It becomes difficult for the students to tell for e.g., if the object is kept near or away from the table [3]. So basically, learners with ID may have problems with spatial relationships, distance, and ordering of objects [3]. It is difficult to remember the information presented in abstract form. This includes numbers and symbols such as minus, greater than, less than other symbols and confusing symbols. +, -, x, <, =, >, %, 6, 9, 5, 2 [3], may also be issued by learners with ID. Identifying numbers is fundamental to mathematics because it helps learners assign meanings to verbal expressions and sounds. Because sounds provide a foundation for learners to understand counting, which is essential for success in both functional and more abstract mathematics [12],[13]. Visuo-spatial thinking, the ability of a person to perceive visual information in the environment, represent it internally, and integrate it with other senses and experiences to derive meaning and understanding, is also associated with intellectually impaired learning. Aligning Numbers in Columns and Rotating Numbers [11], Difficulties in comprehending place values and pictorial representation can also be experienced by learners with ID [3]. Mathematical difficulties can also manifest themselves in the form of numerical discrepancies in learners with ID [10].

2.2.2. Sequencing of Objects (SOO)

The understanding of how a succession of items or actions occurs in a logical order is referred to as SOO.

2.2.3 Difficulty Understanding Time and Money Concept

Time is a practical skill, and learners with ID struggle with time-related issues such as telling time, keeping track of time, estimating time, monetary ideas, and counting money [6].Taking time and understanding the value of money can be difficult for learners with ID [12],[13].Difficulties with the abstract symbols used in mathematics: Learners tend to be confused with the symbols +, -, x, <, =, >, %, 6, 9, 5 ,2 [3]

Challenges with Basic Number Fact: It is difficult for them to understand the derived strategy to get the concluded results, e.g.- 3-4, 3+6, etc. Problems with numerical addition and subtraction [14]. They discovered that learners with syndromic ID (Down syndrome) faced more difficulty than their classmates with non-syndromic ID; in addition, subtraction to

2.2.4. Currently Used Solutions

Using task analysis and manipulative: Special educators frequently employ task analysis, a sequential list of the subtasks or phases comprising a task. It is regarded as one of the important components of the behavioral approach educators use to comprehend and analyze the needs of kids with disabilities.

Manipulative is a frequent approach used in mathematics classes to assist students in learning mathematical concepts. They can be physical or 'concrete,' or virtual or 'abstract.' The physical is primarily concerned with the actual thing, which can be similar or digital. Math concepts can be given more understanding by using visual representations and manipulative. Assistive technology aids learners with ID in understanding math topics.

Using games and play: Play is a fantastic learning method because it is participatory and motivating. Hand-eye coordination, turn-taking, combining objects and spatial skills can all be improved through games [15],[16]. Math stories, songs, and graphic organizers are used. Mathematical storytelling and graphical organizers may assist students with IDs see and comprehending numerical ideas. One method that includes tales and graphical organizers and can help translate solutions to mathematical problems is schema-based strategy training, which is based on cognitive psychology theory [17].

2.3. User Centric Design

The term "User-Centered Design" became popular in 1986 when Donald Norman and Stephen Draper published their book "User-Centered System Design". The term has its roots in human-computer interaction. User-centered design was originally used to design more effective computer interfaces. The main goal is to design solutions that meet users' needs, expectations and perspectives. The basic idea is simple. It involves users throughout the research process. Developers and users often work together to create value for their customers. The key to this approach is connecting with users. Teams practicing user-centered design must constantly interact with their users to gather feedback and develop solutions accordingly. This process should continue throughout the product life cycle rather than stopping after launch. This approach allows you to create a product that helps end users rather than giving those tools they do not need.

Several models have been proposed for implementing user-centred approaches in all kinds of research processes. One of the most popular models is the design thinking model theorized by his Hasso Plattner Institute of Design at Stanford University. The user-centric process goes through five stages.

Stage-1Empathise: The first step is to empathies with the people facing the problem you are trying to solve. These people are called user groups. Talking to user groups and putting yourself in their shoes can help create empathy for them. At this point, research using needs surveys and interviews has often already been done. One may be able to better understand this issue by doing some desk research or consulting an expert. This first step is important to remove previous prejudices and assumptions about the problem and fully consider the user's point of view.

Stage-2 Defining: Next, define the problem in terms of user groups. This is done by carefully analyzing the empathy stage to formulate a problem statement.

Stage-3 Ideas: In the third step, researchers are ready to ask and begin to answer questions about problem solving. Questions like "What can we do to provide more information to our consumers?" This question can be answered in many ways, and brainstorming helps researchers uncover some of the most potential. Many ideas and solutions must be presented before choosing one.

Stage-4 Prototype: Designers then create one or more minimal prototypes of the solution for testing internally or with a small external team. The team goes through trial and error when testing different ideas, always evaluating and re-testing ideas.

Stage-5 Testing: Once the best possible solution has been identified, it can be continuously tested by reviewers or released to the public. This is not the end of the process, instead, the process is iterative. Teams can use insights from testing to redefine issues with the current goal of better understanding users.

2.3.1. Utility Navigation

Navigation that is not entirely related to content and helps users perform different actions is known as utility navigation. It is a less widely discussed but extremely important aspect of experience user. Search bars, login and registration forms, signup, share and print buttons, shopping carts, context menus and tools that allow users to change language or screen size, and fonts are good examples of utility navigation. Designing them is not as simple as it seems; you have to think about what elements one needs, where to place them and how to display them to ensure that our visitors can find them quickly and understand how they work.

2.3.2. Impact Of Utility Navigation On User Experience (UX)

When designing utility navigation, we need to decide how we want users to interact with our website. We need to give them an interaction structure that aligns with our business goals, guides users through the customer journey, provides easy-to-understand options, and provides an immersive experience.

The top priority should be the ability to quickly take the actions the users want. If we allow them to do so, customer satisfaction will increase, and satisfied users will be more inclined to spend more time and money on websites. Next, comes the need for utilities; users do not need extra utilities because too many things will distract attention and reduce concentration. On the tools, which tools are required for our utility navigation and which are independent of the nature of our website should be decided. Third, users must quickly understand what they can do on our website. Visitors do not know what they want, so we always need to inform them about their options.

2.3.3. Assistive Technology

Assistive technology is a broad concept, and according to the International Classification of Functioning, Disability, and Health (ICF), it encompasses any product, instrument, equipment, or technology adapted or specifically designed to enhance the functioning of individuals with disabilities [18]. Teachers are expected to create a warm, nurturing environment where all students feel accepted and respected. While low-tech interventions might be helpful for some, they may not meet the needs of 21st-century learners or those with low-incidence conditions, such as children with autism, those who are both deaf and blind, and those with traumatic brain injuries.

For high-tech assistance, there are ancillary materials that can support students at home and resources designed for classroom use. A wide range of educational software is available to enhance reading skills.

Low-tech and high-tech tools can provide valuable assistance for students who struggle with arithmetic and math. On the low-tech side, students can use their ten fingers to learn counting and perform simple subtractions, such as 8-4=4. Teachers can also use items like pennies, nickels, dimes, and quarters to teach basic units and convey concepts. For example, 5 pennies make a nickel, 10 pennies make a dime, and 25 pennies or 5 nickels make a quarter. This approach helps students understand concepts like equality and subtraction. For multiplication, students can write out times tables, such as 2 x 1=2 up to 2 x 12=24. In terms of high-tech strategies, calculators and cell phones with calculator functions can help students check their work and perform simple calculations. More advanced tools, like Texas Instruments calculators, can compute means and standard deviations. Advanced resources like MathPad enable students to perform arithmetic functions on a computer or cell phone. This is particularly useful for students with cerebral palsy, who may struggle with fine motor skills required for paper-and-pencil math. MathPad offers a talking math program that assists with organization, sequencing, and aligning numbers in columns. It can also produce printed worksheets tailored to individual student needs [19]

3. RESEARCH METHODOLOGY

This research aims to enhance numeracy education for individuals with ID by developing innovative educational tools.

3.1 Participant Selection Criteria

The selection of participants for this study adhered to specific criteria to ensure that the data collected was relevant and insightful. The criteria included:

- NICER Group Members: Due to ethical approval restrictions, participation was limited to members of the NICER Group. This restriction ensures that all participants have informed consent and are protected by ethical guidelines.
- Domain Experts: Recognized field experts were selected for this study. These included:
    - Teachers and teaching assistants from Oakfield School, who have direct experience working with students with ID.

- Researchers from Nottingham Trent University (NTU), who have expertise in special education and the development of educational technologies.

3.2 Ethical Practice Details

- To ensure the ethical integrity of the study, several key practices were followed as follows:
  - Informed Consent: All participants were provided detailed information about the study's purpose, methods, and potential impacts. They were required to provide informed consent, indicating their willingness to participate.
  - Participation Authorization: Authorization for participation was obtained from relevant authorities where necessary, ensuring that all ethical standards and institutional guidelines were met.
  - Data Collection Methods: The study employed a combination of semi-structured interviews, survey forms, and exhibitions of current solutions to gather comprehensive data.

3.3 The Semi-Structured Interviews

Semi-structured interviews were conducted with domain experts, including teachers and teaching assistants who instruct students with varying levels of IDs. These participants were selected based on their extensive experience and ability to provide valuable insights into the educational needs of students with ID.

- Interview Design: The interview questions were meticulously crafted following thorough research and consultations with individuals knowledgeable about the subject matter. This preparatory work ensured that the questions were relevant and could elicit detailed, useful responses.
- Participant Preparation: Participants were informed in advance about the purpose of the interviews, their role in the research, and how their contributions would be utilized. This transparency helped them gain their full cooperation and insightful input.
- Key Questions: Some of the critical questions posed during the interviews included:

  1. Which math e-learning technologies are currently being used by teachers?
  2. What motivates teachers to use these tools, and how are they integrated into the learning process?
  3. Which mathematical concepts do students with ID find most challenging?
  4. How could Augmented Reality (AR) be incorporated into the learning process to enhance understanding?

The primary goal of these interviews was to gain a deep understanding of the existing educational landscape and identify areas for improvement and innovation [20].

***3.4** Survey Forms*

Survey forms were employed as a time-efficient method to gather data from a broader group of experts. These surveys focused on more general aspects of teaching practices and were not limited to numeracy.

- Survey Design: The survey questions were developed based on extensive preliminary research and tailored to gather relevant information about general teaching practices and the potential use of AR in education.
- Key Survey Questions: Some of the questions included:

  1. What teaching practices or methods are commonly used with your students?
  2. Do you believe incorporating AR (3D View) into educational apps would enhance the learning experience and make it more enjoyable?
  3. How do you assess the skills and progress of your students?

The objective of the surveys was to capture a broad perspective on teaching practices and thepotential for integrating new technologies into the learning process.

3.5 Exhibiting The Physical Designed Solution Of Existing AR Application

There was an exhibition organized where different researchers got a platform to highlight the work they have been doing for the betterment of the intellectually disabled and to get suggestions from experts on how to enhance it. As a part of this research, two example activities (design probes) were created keeping in mind how an intellectually disabled would like to learn basic math's skills [21]

They were put out in the exhibition to see if that was a preferred way for experts to get the learning process going. The other aspect was to give them an idea of how these actual activities could be used in either 2D or 3D environments to teach and make it more interesting. The chance of taking the research further to gamification aspect was also mentioned. Figures 2(a) and 2(b) show the designed probes.

(a)

(b)

Figure 2. (a) AR view of Kangaroo (b) Match the Number Game

4. RESULTS AND DISCUSSIONS

This research aims to enhance numeracy education for individuals with ID by addressing conceptual challenges and leveraging the technology. The key insights and methodologies are elaborated as follows.

4.1 Solving the Conceptual Dilemma

"The key thing in terms of education with ID is going back to child development, really thinking of what stage is the young person at so getting a real flavor of their understanding and learning rather than thinking, oh, we can just adapt something that will suit. So, the type of solutions we tend to give them should be appropriate to their age, but the activity can be what we normally associate with younger children. So, providing them with toys will not be a good idea; instead, make it much more realistic," says a senior teacher. Say, if they are 20, they need to deal with things that are more appropriate to them, like, for example, shopping (counting the money), and check the time, but we must keep in mind to design a solution at an exceptionally low level for their understanding. According to experts, the activities created are to be suited for students with more profound disabilities because more efforts are required to make them understand. When they say profound disabilities, they mean the ones that have been brought at 22 weeks (about 5 months). There is a reason; a child is supposed to be in the body for a certain number of months; to allow everything to develop well. But when that does not happen and a child is out early, some of the skills are not developed. That is why it becomes important for teachers to reflect on a child's history to make their future better. The key aspect for us is to design a solution that would be fun to learn and age-specific. The teachers confirmed the explanations for why children with ID may struggle in mathematics, as mentioned in the literature review, via the semi-structured interviews carried out as a part of this research [22],[23]

We can see that the above methods have given us a particularly clever idea about how the current system works and what is expected of us to do to make the learning process easier. From conducting the interviews and talking to the experts, it was seen that the students with ID tend to learn more quickly when being connected to the real world. Mathematics itself is an overly complicated subject, and making it understandable for theID would be a challenge. According to the experts (Teaching Assistants (TA) and Teachers) estimations and measurements like what is heavy or small or how many cookies are on a plate, this area of mathematics is quite difficult for most ID groups to understand and apply. So, it would be a great idea to create something that would help them understand this tougher concept and apply it in their day-to-day life. For example, by giving them a platform where they could visualize a kitchen setup and will be asked to count the cookies in the jar and eat it or filling the cup of water to drink or showing a beach setup and being able to create a sandcastle using the buckets-filling the buckets with sand and putting them one on other. On the other hand, counting numbers is something they tend to grasp quite quickly. The reason is that children love to sing and hear poems; most have numbers in them. They have seen games with dice and dots (numbers) on them. Numbers have been reinforced since they were small, making it a bit easier concept to grasp.

After talking to the experts, it would be a good idea to have words/sentences along with the visual aspect. For instance, if we want them to count the cake pieces on the plate, we can tag along words like "cake",and "plate" just to reinforce the relation of words to the picture. The experts prefer to have a voice-over and be specifically a recorded voice instead of a robotic one, as they think that real voice tends to create a sense of enthusiasm in students and familiar voices (that of their teachers, parents, and careers) make them feel comfortable. As our research is focused on deriving a technological solution, it becomes important to see what experts think about technology and the solutions designed. The response was quite mixed. A few of them agreed that it was useful, while others did not, but it all came down to the type of group they were working with. They all agreed that software is a reinforcing tool in education. That means it helps them assess the child's skills repeatedly and in different ways. But they were keener on practical aspects being brought into existence. That is, even if there are existing solutions that teach them how to give change and count the money,it would be better for them if once they are taken to a real supermarket and asked to do it in real life.

4.2 Addressing the Math Problem

A lot of similarities can be drawn from the literature review section titled"Difficult Areas of Math for students with ID" and the above analysis. It is important to consider that most difficult mathematics concepts need to be addressed. Any future solution should be designed to make it easy to understand the toughest concepts. By analyzing the results and reading the literature, we can say that some of the most important concepts are considered the toughest for the people of ID to understand. For example, by saying the distance between things or deciding if an object is near or far from them, telling what time it is or counting the money given to them. These are some important areas in our day-to-day life, and they need to understand this.

4.3 Focusing On User Interface Design

The researchers were able to analyse that when working with a pupil having a certain intellectual disability it becomes necessary to focus on visual representation and therefore an attempt was made to utilize visual aids, such as illustrations, diagrams, or pictorial representations, to facilitate understanding. Therefore, presenting math concepts through visual elements can enhance comprehension for users with ID who may struggle with abstract or symbolic representations. Incorporating interactive elements like quizzes, games, or interactive exercises toinvolve users in the learning process actively becomes a need, and this can enhance engagement and motivation while providing immediate feedback on progress. Consider incorporating multiple sensory modalities to cater to diverse learning styles. For example, provide audio explanations or narration alongside visual content to ease learning.

4.4 Usage of Assistive Technology

AT matching approaches consider personal needs and preferences in four key areas: person-centric (focusing on individual strengths, weaknesses, and support), environment-centric (considering the learning setting and support systems), task-centric (aligning with specific objectives and required functions), and technology-centric (selecting suitable assistive tools). Here, the researchers have made use of technology-centric Assistive Technology. Examples can be text-to-speech, speech-to-text, etc.

4.5 Disability Specific Physical Model

The experts work with students with different disabilities, so each one needs would vary. There are diverse types of disability, including visual, hearing, motor, and so on. So, having a physical design probe could be suitable for all simultaneously. The possibilities can be endless!

4.6 Data Visualization As A Boon

Through talking to experts and detailed research, we have come to know that visualization plays a key role in life, especially in the academic life of the ID. Any concept can be easily conveyed through visualization. Similarly, Tableau, a data analysis and visualization tool, can help the ID understand the data through visualizations. The key point to be noted here is that Tableau does provide a way to create accessible dashboards so that anyone can understand them.

4.7 Use Cases and Analysis

4.7.1 Accessible Design

Use Case: A web application designed for intellectually disabled students incorporates features such as large, high-contrast fonts, clear navigation menus with descriptive labels, and customizable color schemes to accommodate different visual and cognitive needs.

Analysis: Accessible User Interface/User Experience (UI/UX) design ensures that the ID students can easily navigate and interact with digital interfaces, promoting inclusivity and usability for all users. By prioritizing accessibility features, designers can create a more inclusive learning environment that caters to diverse needs and abilities.

4.7.2 Simplified User Interfaces

Use Case: A math learning app for intellectually disabled students features a minimalist user interface with intuitive icons and straightforward instructions. Complex menus and options are streamlined to reduce cognitive overload and make the app more user-friendly.

Analysis: Simplified UI/UX design eliminates unnecessary clutter and complexity, making it easier for intellectually disabled students to focus on learning objectives without getting overwhelmed by extraneous details. By prioritizing simplicity and clarity, designers can enhance the usability and effectiveness of educational tools for this demographic.

4.7.3 Visual Feedback and Reinforcement

Use Case: A gamified language learning platform provides immediate visual feedback and positive reinforcement for correct answers, such as animated rewards or progress indicators. This visual feedback encourages intellectually disabled students to stay engaged and motivated while reinforcing learning objectives.

Analysis: Visual feedback and UI/UX design reinforcement elements enhance the learning experience by providing immediate feedback and positive reinforcement for desired behaviors. By incorporating interactive and engaging elements, designers can create a more stimulating and rewarding learning environment for intellectually disabled students.

4.7.4 Customizable Learning Paths

Use Case: An adaptive learning platform allows ID students to customize their learning paths based on individual preferences and learning styles. Students can choose from various interactive activities and multimedia resources tailored to their unique needs and interests.

Analysis: Customizable learning paths empower intellectually disabled students to take control of their learning experiences and pursue topics at their own pace. By offering flexibility and personalization options, designers can accommodate diverse learning preferences and abilities, maximizing engagement and learning outcomes.

4.7.5 Assistive Technologies Integration

Use Case: A reading comprehension app for intellectually disabled students integrates assistive technologies such as text-to-speech functionality and word prediction tools to support literacy development. Students can listen to text read aloud or receive predictive suggestions to aid in comprehension and vocabulary acquisition.

Analysis: Integrating assistive technologies into UI/UX design enhances accessibility and usability for intellectually disabled students by providing additional support and accommodations. By leveraging assistive technologies, designers can address specific learning challenges and empower students to overcome barriers to learning.

4.7.6 Feedback Mechanisms for Improvement

Use Case: An online assessment platform provides detailed feedback and performance analytics to help intellectually disabled students track their progress and identify areas for improvement. Students receive personalized recommendations and resources based on their performance, fostering a growth mindset and continuous learning.

Analysis: Feedback mechanisms in UI/UX design facilitate self-assessment and reflection, enabling intellectually disabled students to monitor their progress and take ownership of their learning journey. By providing actionable feedback and resources for improvement, designers can support students in achieving their academic goals and building confidence in their abilities.

5. LIMITATION AND FUTURE WORK

The major limitation of this research was it is general approach. The broad scope resulted in many research questions remaining either unanswered or receiving similar responses. This outcome is primarily attributed to the diverse nature of the participant group, which included individuals with varying degrees and types of ID. This lack of specificity hindered the ability to derive precise and actionable insights tailored to distinct subgroups within the ID population.

5.1 Limitations Of The Broad Approach

- *Homogeneous Data*: The general approach led to homogeneous data, with many participants providing similar answers. This limited the ability to identify nuanced needs and preferences specific to particular subgroups of individuals with ID.
- *Unanswered Questions:* Some research questions were not adequately addressed due to the broad participant base. Participants' diverse cognitive and functional levels made it challenging to gather specific insights.
- *Generalized Findings:* The findings were too generalized, reducing their applicability to specific contexts or individuals. This limited the potential to develop targeted interventions or educational tools that cater to the unique needs of smaller, more defined groups within the ID community.

5.2 Opportunities For Future Research

- Despite these limitations, the research provides a foundation for more focused future studies. Here are some potential directions:
- *Narrowing the Focus:* Future research should focus on specific subgroups within the ID population. For example, selecting a specific age group, type of intellectual disability, or functional level would allow for more detailed and actionable insights. This targeted approach could lead to developing specialized educational tools and strategies.
- *Specialized Research Questions:* Developing research questions specific to the chosen subgroup would

ensure the data collected is relevant and useful. This specificity would help understand the unique challenges and needs of the subgroup, leading to more effective interventions.

- *Utilizing 2D and 3D Teaching Approaches: The* research highlighted the potential benefits of using two-dimensional (2D) and three-dimensional (3D) teaching approaches. Future studies could explore the development of interactive and immersive learning environments using AR to teach basic concepts of numeracy and literacy. This approach could make learning more engaging and effective for students with ID.

5.3 Implementation of Future Research Directions

- *Identify Specific Subgroups:* Determine the specific subgroup to be studied, such as adults with mild to moderate ID or children with severe ID.
- *Design Tailored Research Instruments:* Develop research tools and questions tailored to the needs and capabilities of the chosen subgroup. This could include interviews, surveys, and observational studies.
- *Develop and Test AR-Based Educational Tools*: Create AR-based educational tools designed to teach basic numeracy and literacy concepts. These tools should be tested with the selected subgroup to evaluate their effectiveness and engagement levels.
- *Collect and Analyze Data:*Use tailored research instruments to collect and analyse data from the targeted subgroup. Analyze the data to identify specific needs, preferences, and challenges.
- *Iterate and Improve*: Use the insights gained from the data analysis to refine and improve the AR-based educational tools. Conduct iterative testing and refinement to ensure the tools are effective and engaging.

While the broad approach of this research posed limitations, it also opened opportunities for more focused and specific future studies. Future research can provide more precise and actionable insights by narrowing the research scope and utilizing innovative teaching methods like AR. This will ultimately lead to developing more effective educational tools and strategies for individuals with ID.

6. CONCLUSIONS

The primary objective of this research was to obtain a comprehensive understanding of the current state of learning for students with ID. This foundational knowledge is essential for identifying gaps and opportunities in the existing educational landscape and informing the development of more effective learning environments tailored to the unique needs of these students. To achieve this, the research sought to map out the existing educational tools, methods, and approaches being used to teach students with ID. This involved gathering insights from educators and experts through semi-structured interviews, surveys, and observational studies. By identifying the strengths and limitations of current practices, the research aimed to highlight areas that require enhancement.The insights gained from the current study are intended to serve as a foundation for developing advanced educational environments. The research emphasized the potential of incorporating two-dimensional (2D) and three-dimensional (3D) technologies, including AR, to create more engaging and effective learning experiences. These advanced tools are envisioned to address the specific learning challenges faced by students with ID, making abstract concepts more tangible. The authors acknowledge that this research is an initial step towards a broader goal of improving educational outcomes for students with ID. The broad approach taken in this study provided valuable general insights but also highlighted the need for more targeted research to address specific needs within this diverse population. To build on the findings of this study, future research should target specific subgroups within the ID population, such as students with mild, moderate, or severe ID. This targeted approach will allow for more detailed and actionable insights, facilitating the development of specialized educational interventions. Furthermore, developing specialized research instruments tailored to the needs and capabilities of these specific subgroups is crucial. This could include designing more precise interview questions, developing specialized surveys, and employing observational techniques catering to the participant's cognitive and functional levels. Leveraging advanced technologies, such as AR, to create immersive and interactive learning environments can help make complex concepts more accessible and engaging for students with ID, enhancing their learning experience and outcomes. An iterative process of testing, feedback, and refinement involving collaboration with educators, students, and other stakeholders will ensure that the educational tools developed are effective and meet the needs of the students.

Longitudinal studies should be conducted to assess the long-term impact of the newly developed educational tools and approaches. This will help determine the sustainability and effectiveness of these interventions over time, providing valuable data for further refinement and development. This research serves as an initial exploration into the educational needs and challenges faced by students with ID. The findings underscore the necessity for more targeted and specific research to develop effective educational tools. By leveraging advanced technologies and adopting a focused approach, future research can significantly enhance students' learning experiences and outcomes with ID. The authors recognize that while this study provides a valuable starting point, ongoing and iterative research efforts are essential to making learning easier and more accessible for individuals with ID.

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AUTHOR CONTRIBUTIONS

VishvjitThakar : Enabling Tool and Technology Suggestions.
Romany Thakar: Data collections, Visit to Schools, Understanding, Simulation and Documentation.
Pratik Vyas: Supervision, Literature Review, Discussion and Conclusion.

CONFLICT OF INTERESTS

Authors do not have any conflict of interest.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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