**Usability Evaluation: User Experience Evaluation for Dyscalculia Students using Augmented Reality in Mathematics**

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**Abstract.** Augmented technologies have found to be an effective approach for special needs learners in enhancing their learning skills. On the other hand, these applications must be designed in such a way that they are usable and intuitive for individuals with special needs specially dyscalculia students. Usability evaluation on user interface is an informal method of usability analysis evaluation which presented within an interface design and required experts to commented on it. Usability evaluation principles applied focused to improve the efficiency and learnability of the applications The usability evaluation involved summative evaluation which was conducted on the use of the application by fifteen (15) elementary dyscalculia students. Finding of the research indicated that the important for early intervention through embedded in Augmented Reality application was certainly significant to assist dyscalculia students to learn mathematics. The result outcome shows that usability evaluation on user interface has evidence a break in the field of special needs students.

**Keywords:** Dyscalculia,Augmented Reality, Mathematical Difficulty, Usability evaluation, Visual Based, Cognitive walkthrough, Informal Walkthrough

1 Introduction

Diverse technologies were used to evaluate Augmented Reality for Dyscalculia students’ application testing vital to ensure the efficiency and learnability of the working prototype for elementary dyscalculia learners. There is a major difference between Augmented Reality (AR), and traditional interfaces due to their differences in physical environment. AR has a complicated environment in which users mainly move freely as well as moving parts of their physical body to interact with the application. The various strategies used to collect data were employed such as informal and cognitive walkthrough embedding questionnaire and expert evaluation. The diverse techniques used in date collection uncovered various aspects of how learning for dyscalculia learners can take is various form apart from the traditional conventional approach.

In 1981, usability evaluation design by Shackel emphatically sought to replace the application as a user-friendliness phase. Learnability, throughout, adaptability and attitude are the four (4) components of usability evaluation that are of interest (Shackel 1990). The four (4) characteristics of usefulness, effectiveness (easy of use), learnability, and attitude (likeability) articulated by Shackel (1990) and Booth (1989) are included in Rubin's (1994) definition of usability. In generally usability testing consists of three (3) feature as easy to learn, easy to use and user satisfaction to use an application (Stone, Jarrett & Minocho 2005; Smith, & Mayes 1996). Usability refers to efficacy and efficiency in achieving defined goals and user satisfaction based on international standards.

Usability standard is described as "the extent to which a product may be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified content use" by ISO 9241 (1998). However, usability testing has considerable effects on learning applications for students with dyscalculia. Additionally, a dyscalculia supportive Augmented Reality learning application should experience usability testing to confirm that it meets both its learnability and efficiency standards (Gresse von Wangenheim et al. 2016).

**2 Objective**

Summative usability evaluation goal is to assess dyscalculia students at the conclusion of a course by comparing them to a standard. The end does not refer to the finish of a whole course or module of study. Summative evaluation may be distributed throughout a lesson after a particular lesson that is taught, and there are advantages to doing so. The technique of summative evaluation employed in AR learning application prototype was aimed to summarise overall learning after the intervention was through informal walkthrough and cognitive walkthrough.

**3 Methodology**

The process of usability evaluation which includes summative review focuses on satisfactory way to understand and use the program to accomplish their goals. It is about the degree of user satisfaction with the evolve Augmented application (Nayebi, Desharnais & Abran 2012). Summative evaluation was also adopted to access the goal of the Augmented Reality application in fulfilling the stated intended goal.

Usability testing was done as part of the summative evaluation process using a sizable sample of representative users. Aimed at identifying the advantages and disadvantages as well as contrasting various design options or related applications. The summative evaluation involved assessing the impact of efficiency and learnability of the application. Summative evaluation refers to the assessment for the learning of participants where the focus is on the outcome of a learning application. These contrasts with formative evaluation, which summarises the participants' development at a particular time.

The methodology based on Table 1 can be used to collect information from the target users. The informal walkthrough technique was a fundamental method for gathering data about the application's intended usage, embedded cultural meanings and indicated ideal users use. The informal walkthrough technique indicates that the user allows to explore the use of the application at their own pace and in the order that they see fit without the researcher getting in the way. This method can be used to assess how user-friendly and intuitive the application is. Usability evaluation instrument used during the summative evaluation for the Augmented Reality learning application as working prototype was developed to collect data on usability evaluation of the prototype. Once the elementary dyscalculia learners were comfortable using the AR learning application, information retrieve using a informal walkthrough strategy as shown in Table 1. The cognitive walkthrough technique was used to identify usability issues in an interactive application. It focuses on how easy for a new user to accomplish tasks with the application.

**Table 1**. Summary of Usability Evaluation Methods for Augmented Reality Application

|  |  |  |
| --- | --- | --- |
| **Type of evaluation** | **Evaluation Method** | **Implemented** |
| Summative Evaluation | Informal Walkthrough | Allows participants to explore the system without preparing a thorough test task. |
| Cognitive Walkthrough | Primarily focus on ease of use and confidence as first time users. |

**3.1 Usability Test Sampling**

As many as 35 students from an elementary school who were found to have dyscalculia symptoms made up the sample size. In all, fifteen (15) samples were used in the usability test. These students had dyscalculia, according to a screening. through a specially built screening tool (DYScrin), using a random sample technique. These students were identified as dyscalculia students during screening using a specially designed screening tool (DYScrin) using a random sample method. One of the state's national schools in Selangor hosted the study. Purposive sampling, a non-probability sampling technique used in this study, selects respondents based on a set of criteria, such as similarity in academic background, learning style, and attitude to the learning environment. According to Nielsen (2000), a sample size of three (3) to five (5) persons is adequate for usability testing because only three users are needed to identify 80% of all usability issues.

**4 Finding and Discussion**

Data was gathered by observation, informal walks, and cognitive walks. The efficiency and learnability of dyscalculia students were the two (2) constructs on which the usability testing was based. Additionally, information was gathered by observation, informal walks, and cognitive walks. The efficiency and learnability of dyscalculia learners were the two (2) constructs used to guide the usability assessment.

**4.1 Findings on Learnability Construct**

The application utilization of the learnability construct was branched into two (2) components which are interactive environments in both the real world and augmented reality environment as the instrument used to gather and measure data on the aforementioned instrument that evaluates the learnability construct. The sections utilized to assess the learnability qualities are listed in Table 2. The learnability construct of Augmented Reality application is measured using a rubric that has been modified from Nielsen's (2001) earlier research on learnability features.

**Table 2**. Construct on Learnability Assessment Rubric

|  |  |
| --- | --- |
| **Scale** | **Explanations** |
| F | Fail: unable to complete the assignment despite assistance |
| PS | Partial success: able to complete the task after receiving assistance |
| S | Success: competent to work without assistance |

Usability testing based on the learnability construct is evaluated using the Usability Testing Analysis Model I: Learnability construct (UTCMI: Learnability construct) as in Figure 1.

**Likert Scale**

F

(Fail)

AS

(Almost Success)

S

(Success)

**Construct Learnability**

Set of Usability Tasks List 1 UTC 1: Real World Environment

Set of Usability Tasks List 2 UTC 2: Interactive AR Environment

**Respondents**

15 Elementary regarded of dyscalculia learners

Usability Testing aspects of User Interface Construct: (Learnability)

**Usability Testing**

(Construct: Learnability)

**Instrument**

Usability Task List Review

**Figure 1**. Usability Testing Analysis Model 1: Learnability Construct (UTAM1: Learnability)

The following challenge was completed by the dyscalculia students using the provided tool Usability Tasks List 1: Table 3 presents results from the study on task success for the Learnability Construct (UTC 1). The values in Table 2 are built on the components in Table 3 as their base.

**Table 3** Usability Testing Construct Task for Learnability construct

**Learner Task List**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** | **T9** | **T10** | **T11** | **T12** | **T13** | **T14** | **T15** | **T16** | **T17** | **T18** | **T19** | **T20** |
| S1 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S2 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S3 | S | S | AS | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S4 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S5 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S6 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S7 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S8 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S9 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S10 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S11 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S12 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S13 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S14 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| S15 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| (%) | 100 | 100 | 93.3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Mean | 2.00 | 2.00 | 1.93 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Standard Deviation | .000 | .000 | .258 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

Based on a formula developed by Nielsen (2001), Usability testing construct was used to calculate the success rate score in Table 3. The students attempted the tasks a total of 300 times (students x task list). Number of 299 students those attempts were successful and one (1) student was partially so. For each partial success 50% of a point was awarded. The Usability Testing task for learnability construct success rate is as according:

Success outcome = Success + (Almost Success x 0.5) / attempts perform x 100

= 299 + (1 x 0.5) / 300 x 100

= 99.8%

According to the findings of the Usability Testing Construct Task for Learnability indicates that the Augmented Reality application for dyscalculia students was very positive scoring for successful outcome which indicates that the students were able to complete the tasks on their own.

Another test was administered towards the dyscalculia students, usability testing construct task for the learning prototype interactive augmented reality environment as in Table 4. Task 2 usability testing success rate is as according:

Success outcome = Success + (Almost Success x 0.5) / attempt perform x 100

= 101 + (4 x 0.5) / 105 x 100

= 98%

The usability testing was designed to determine the success outcome of dyscalculia students in order to give a broad overview of how the application supports them and how much work is still needed to make it more accommodating for these students. The finding of the student informal walkthrough results on the learnability construct reveals that the construct score in the real world environment is minimal higher than it is in the interactive AR environment usability testing.

This may be as a result of dyscalculia student present newly discovery to the augmented reality learning environment. However, there was no difference in the success outcome attained for usability testing tasks 1 and usability testing tasks 2. Therefore, it can be summarized that the learnability based on the augmented reality interactive learning environment was highly favourable, at the success outcome which implies the students were able to complete the tasks on their own pace.

**4.2 Findings on Efficiency Construct**

The efficiency construct was assessed using the UTAM 2: Efficiency construct from the Usability Testing Analysis Model. Efficiency is define as a way to gauge how long it takes to complete a task. It is often the amount of time needed by participants to finish a job assigned in any given module. There are two ways to calculate efficiency construct which is the overall relative efficiency and time-based efficiency.

While time-based efficiency referred to the measurement of the amount of time spent by the students to complete the task, overall relative efficiency referred to tests conducted on the students who successfully completed the task in comparison to the total time taken. Table 5 displays the efficiency construct as measured by how long it took the students to finish the exercise. The efficiency construct of the augmented reality prototype application has been measured using the usability metrics rubric for efficiency attributes which has been modified from the earlier study of Nielsen 2001b.

**Respondents**

15 Elementary regarded of dyscalculia learners

End User Usability Testing aspects of User Interface (Construct: Efficiency)

**Attribute**

Start Time / End Time

**Dichotomous Questions**

Yes

No

**Usability Task Checklist 2 Construct Efficiency**

Check List: Learners Achievement

**Usability Testing: Cognitive Walkthrough**

(Construct: Efficiency)

**Instrument**

Usability Task Checklist 2 (UTC 2)

**Figure 2**. Usability Testing Analysis Model 2: Efficiency Construct (UTAM 2: Efficiency)

**Table 4.** Efficiency Construct: Time Taken to complete Task

|  |  |  |
| --- | --- | --- |
| **Learner** | **Time taken to complete the Task (minutes)** | **Time taken to complete the Task (seconds)** |
| S1 | 15 minutes | 900 |
| S2 | 10 minutes | 600 |
| S3 | 15 minutes | 900 |
| S4 | 10 minutes | 600 |
| S5 | 10 minutes | 600 |
| S6 | 15 minutes | 900 |
| S7 | 20 minutes | 1200 |
| S8 | 15 minutes | 900 |
| S9 | 15 minutes | 900 |
| S10 | 15 minutes | 900 |
| S11 | 15 minutes | 900 |
| S12 | 15 minutes | 900 |
| S13 | 15 minutes | 900 |
| S14 | 25 minutes | 1500 |
| S15 | 20 minutes | 1200 |

Overall Relative Efficiency is calculated as follows:

Where :



Where :

N: number of tasks ( N=1)

R: number of users ( N=15)

nij result for the task (i) by the user (j) If the task is completed successfully, then

nij=1 otherwise nij=0

tij time spent the user ‘j’ to complete the task ‘i’. If the students are unable to properly accomplish the task, time will be counted down from that point until the students give up. The efficiency construct measure based on the overall Relative efficiency is displayed in Table 6. Following is how the overall efficiency was determined:

=(1\*900+1\*600+1\*900+1\*600+1\*600+1\*900+1\*1200+1\*900+1\*900+1\*900+1\*900+1\*900+1\*900+1\*1500+1\*1200) x 100%

(900+600+900+600+600+900+1200+900+900+900+900+900+900+1500+1200)

= 100%

This is how the Time Based Efficiency is determined:



Time based Efficiency =

= (1\*900+1\*600+1\*900+1\*600+1\*600+1\*900+1\*1200+1\*900+1\*900+1\*900+1\*900+1\*900+1\*900+1\*1500+1\*1200) (1\*15)

= 920 (goals/seconds) / 15.33 (goals/minutes)

**Table 6**. Overall Relative Efficiency to Complete Task Efficiency Construct

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Learner** | **Time taken to complete the Task (minutes)** | **Time taken to complete the Task (seconds)** | **Time based Efficiency** | **Overall Relative Efficiency** |
| S1 | 15 minutes | 900 | Time<=920s | 100% |
| S2 | 10 minutes | 600 | Time<=920s | 100% |
| S3 | 15 minutes | 900 | Time<=920s | 100% |
| S4 | 10 minutes | 600 | Time<=920s | 100% |
| S5 | 10 minutes | 600 | Time<=920s | 100% |
| S6 | 15 minutes | 900 | Time<=920s | 100% |
| S7 | 20 minutes | 1200 | Time>920s | 100% |
| S8 | 15 minutes | 900 | Time<=920s | 100% |
| S9 | 15 minutes | 900 | Time<=920s | 100% |
| S10 | 15 minutes | 900 | Time<=920s | 100% |
| S11 | 15 minutes | 900 | Time<=920s | 100% |
| S12 | 15 minutes | 900 | Time<=920s | 100% |
| S13 | 15 minutes | 900 | Time<=920s | 100% |
| S14 | 25 minutes | 1500 | Time>920s | 100% |
| S15 | 20 minutes | 1200 | Time>920s | 100% |

Based on the results of the cognitive walkthrough study was determined that Time Based Efficiency measures 15.3 seconds of the time needed to complete the activity by the dyscalculic learner. In terms of the total time taken to complete the exercises, the overall relative efficiency of the fifteen (15) dyscalculia students demonstrated that 100% of them finished the tasks effectively. The assignment was attempted by three (3) dyscalculia learners (L7, L14, and L15) as can be shown, however they took longer overall to complete it than the other dyscalculia learners.

When using the tangible method, children were more engaged and had more fun. The severely disabled youngsters enjoyed using their interactive physical system. It is supported as based of Fan et al. (2017) discovered that the majority of students enjoyed utilising the physical application and wished to do it once more. Additionally, the current study showed that all students used the application and the physical objects without any trouble. Through the informal and cognitive walkthrough, none of them encountered any challenges that led to a successful outcome. Children can readily comprehend how to utilise the AR application, according to Antle et al. (2011). They had no trouble using the AR application during the learning phase. Additionally, claimed that users with learning difficulties picked up on the application rapidly. According to these, it was discovered that the kids said the AR tangible technology was simple to use.

**5. Conclusion**

For the current analysis to find the theoretical gaps that are relevant, prior literature was essential. The study covered topics such as the identification and early detection of dyscalculia students, the approach field of Augmented Reality (AR) in education, the advantages of Augmented Reality technology for learning tangible user interface (TUI), application development principles, usability inspection and usability testing. It also covered the approach of behaviourist theory and cognitivist theory underpinning the use of Augmented Reality (AR) assistive learning technology for dyscalculia students. To uncover components suited for teaching and learning the fundamentals of mathematics for dyscalculia learners utilising AR technology, the theoretical gap between cognitivist and cognitive learning theories was examined. In order to design and develop an AR learning application that can truly meet the needs of dyscalculia learners taking into account their learning difficulties, important components such as an integrated design and development LD application model that incorporated with the Iterative-Evolution model and the Human-Computer Interaction (HCI) development model.

The other aspects that need to take into consideration as the suitable for dyscalculia learners; the pedagogical approach in relation to visual materials and visualisation due to the preferred approached of dyscalculia learners in learning mathematics particularly the abstractive aspects of mathematics, where there is need for them to visualise. Therefore, the more attributes of dyscalculia learners are known, the more accurate would be the design of the learning application for them. A cognitive tour is a technique for testing usability that is geared towards novice users and involves the examiner completing a number of task scenarios. Learnability and efficiency are amidst the usability testing components.

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