# A Color Sensing AR-Based Interactive Learning System for Kids

Maryam Tayefeh Mahmoudi
Multimedia Research Group
IT Research Faculty, ICT Research Institute
Tehran, Iran
mahmodi@itrc.ac.ir

Farnaz Zamiri Zeraati
Computer Engineering & IT Department
AmirKabir University of Technology,
Tehran, Iran
farnazzamiri@aut.ac.ir

Parham Yassini
Computer Engineering & IT Department
AmirKabir University of Technology,
Tehran, Iran
parhamyassini@aut.ac.ir

***Abstract*—In the last decade, there has been a rapid growth in applying Augmented Reality (AR) and Internet of Things (IoT) as emerging technologies in linking physical and virtual objects for educational purposes. Realizing the complex concepts in a way that learner be able to interact with, will not only elevate the learning passion, but also has a significant positive role on learning performance and student's engagement.**

**According to the aforementioned points, in this paper, we propose a color sensing AR-Based interactive learning system for kids which helps them to scan and explore the colors and learn their corresponding words in Spanish language.**

**Our aim is to explore the role of such an AR-IoT-based system on students' learning performance. To do this, an embedded system including a color sensor and a raspberry pi board was implemented and provided for the kids. By placing the sensor on the specially designed colored book, the light's color frequency is measured and RGB code is sent over the cloud using MQTT protocol. On the web application side, color data is fetched from the cloud server and learners will be provided with a real-time feedback with the corresponding animations and multimedia content that teaches colors in Spanish language. Students' learning performance was assessed using paired t-test based upon the results of their pre-test and post-test, before and after interacting with the system. The successful experimental results were achieved proving the effectiveness of the system on learning performance.**

**Keywords—Augmented reality, internet of things, color sensing, interactive learning.**

## I. INTRODUCTION

In the last decade, there has been a massive rise in popularity of educational technology systems, and the role of digital devices has become more prominent in almost every aspect of education. In the scope of educational technology, the main concept is to make the conventional educational content more impressive, yet effective by adding interactiveness and using multimedia contents. In order to interact with the digital domain easily, augmented reality (AR) technology, as well as Internet of Things (IoT), has come to aid. It makes educational content more tangible by augmenting video, audio or 3D models.

It is also worth mentioning that, internet of things (IoT) is the network of physical objects connected to the internet [1]; considering this concept we employed principles of IoT in implementing our system, therefore, the dependency constraint is minimized and any personal devices like laptops, tablets, smartphones and etc. can be used by the learners. Our proposed approach is motivated by recent studies revealing the potential of multisensory learning in enhancing children's learning performance [2], especially the ones focusing on children with difficulties in sustaining attention or other learning disabilities [3].

Our goal is to design a system which lets children use the mentioned embedded system equipped with a color sensor to explore the color of their surroundings or our specially designed colored book and simultaneously watch the related educational animations on their web browser.

Taking the above points into account, this paper presents a new approach to implement an interactive IoT-based system with augmented reality capabilities. However, the proposed system uses a low-cost color sensor for getting information from learner's environment, an embedded system is implemented in order to analyze raw sensor data, and a cloud service is employed for data transfer between the embedded system and the client side web application. On the other side, a web application is implemented on which the engaging educational content will be presented to the user depending on the color of the object in real-time. Integrating AR-based and IoT-based systems provides an interactive and effective platform that makes virtual content more alive and interesting for learners; as is confirmed by our achieved results.

This paper is divided into five chapters; with the introduction being the first, the second chapter gives an overview of related works that have been done revolving around the topic. In the third chapter, the components of the proposed system and the interoperability between its components are described. We report the results of our conducted tests in chapter four, leaving the conclusions and explaining future works for the final chapter.

## II. RELATED WORKS

Multisensory perception and interactiveness in context of education have been proven to have a significant impact on learning performance. In this respect, interactive and multimedia augmented reality (AR) based solutions from one side and IoT-based solutions from the other side, have become important topics of research over the last decade [4, 5].

AR-based learning systems often get the traditional educational content from real-world sensory inputs, augmenting them with multimedia contents as well as 3D Objects. While IoT-based educational assisting systems usually provide a platform for interacting with physical & virtual objects to increase the understanding of a complex issue [6]. Taking the above facilities into account may lead to remarkable excitement in the learning process, eventuating better learning performance.

Different approaches have been proposed in this area, whose major changing factors are the types of multimedia content, target of educational field, requirements, types of input and intended outcomes, and also the type of mobile applications and server platforms as well as embedded systems. For instance, constructing and applying 3D objects in AR-based application for mathematics and geometry education [7] as well as chemistry and physics virtual laboratories [8,9] have a significant role in learning performance. These approaches have also been used for learning languages [10], science and biology [11, 12]. On the other hand, several studies, like [3] and [13] have been carried out, mainly focusing on finding new solutions to facilitate learning for users with learning disabilities or autism.

A fundamental challenge in this scope is keeping track of real-world events and providing the appropriate feedback with a tolerable delay. In the most common approach, these systems use cameras and computer vision methods to get the current state of real-world, and a graphics workstation (such as personal computer, mobile device, etc.) is in charge of processing and adding the virtual content to the real-world percepts which is rendered and displayed on an AR display later [14]. In more recent studies, complex processes on visual inputs are done using a cloud-based approach, [15] which leads to lower costs on the client side and enhanced processing performance. In this scope, system's real-world state recognition is done by adding some specific elements. In most cases, some specific elements like 2D barcodes [10, 16], dotted patterns [16] or RFID tags [17] are employed to make real-world objects recognition possible for the system.

In addition, recent developments in IoT have led to an evolution in education field in different aspects such as information accessibility, human interaction, campus security, energy saving and etc. A recent review of the literature on this subject [18] explained the application of sensors in augmented reality based interactive learning environments. A wide variety of sensors have been employed in the past studies but no one, to the best of our knowledge, has studied the application of color sensors in this field. Meanwhile, these sensors have been used in some other applications like aiding color blind people [19]. One of the major drawbacks to exploiting these systems is their initial requirements. In some cases classroom needs to be equipped with special cameras [13] and special AR displays. Moreover, well-designed virtual objects and environment are also needed to present the desired output to the learners [7].

As a conclusion, appropriate educational content, feasibility, ease of use and required hardware and software are all essential elements to be considered when designing AR-based or IoT-based learning systems. In addition, the capability of being self-instructional and the level of interaction are also important, especially for kids and students with learning disabilities.

Another concerning fact is the required method to evaluate learning performance of such systems. To do so, employing Felder-Silverman's learning style model [20] and/ or cognitive layers of Bloom [21, 22] or user experience questionnaires, etc. seem to be usually very helpful [23, 24].

## III. PROPOSED SYSTEM

### A. *Utilizing Internet of Things in Our Proposed System*

IoT has opened up new prospects for interaction between humans and objects, by making machine-to-machine and human-to-machine communications possible. By employing sensors, objects would be able to recognize their surroundings and act in an intelligent way. Consequently, IoT is facilitating educational devices in multiple ways including embedded system, mobile application and server.

According to [25] three main components required for IoT computing are as follows:

a. Hardware, consisting of sensors, actuators and embedded systems.

b. Middleware, expressed by tools for data cloud and big data analytics.

c. Presentation, easy to understand visualization for end users.

Taking the above points into account, we have designed a color sensing AR-Based interactive learning system for kids to learn colors in Spanish language. In this regard, first, color detecting sensors collect data from the environment, then the collected data is sent over the cloud and on the other side, the corresponding multimedia educational content will be displayed on the learner's browser, immersing them in an educational environment using animation, sound, and video.

In our proposed system, learners can point the color sensor to real-world objects (or a specifically designed colored book), and then be presented with corresponding educational animation to learn colors in Spanish language, specially designed for kids.

### B. *Framework of Proposed System*

The framework of our proposed system is shown in Figure 1. As illustrated, an embedded system is designed to detect and send the color data. Color sensor detects the color of objects, and a Raspberry Pi board is used for the real-time processing of sensor's raw data. Mentioned board publishes the color data to the cloud MQTT server (MQTT Broker) in RGB format.

On the other side, a web application is implemented for presentation of the augmented educational contents. The web server subscribes to the MQTT server and fetches the real-time data, and based on color, appropriate animation and videos will be displayed on the browser. This will make our system device independent and since almost no computation is done on the client-side, any internet connected device like laptops, tablets and smart phones can act as the visual platform.

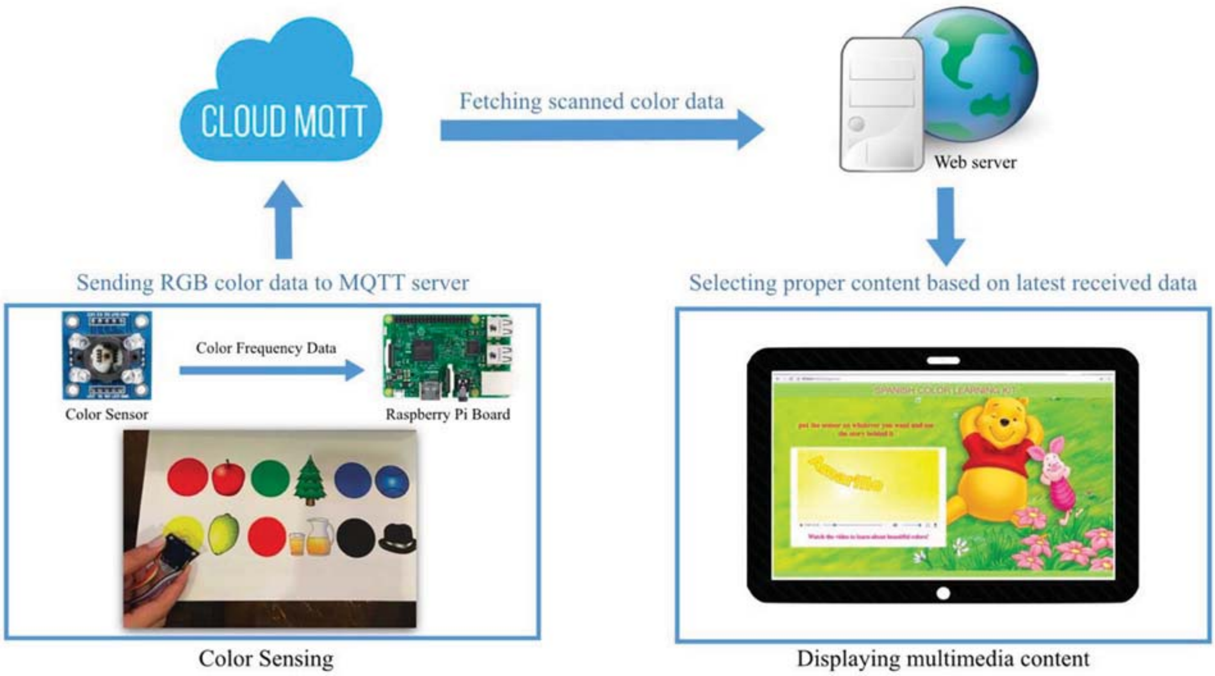


Figure 1. Framework of Proposed System

- ***Color sensing system***

The sensor employed for this purpose was TCS3200 which is a color light-to-frequency converter [26] and a single-board small computer "raspberry pi model B+" was used for processing the raw data sent from the sensor and handling the data transmission over the internet.

Output from the mentioned sensor is a square wave pulse which will be counted during a period of time in order to obtain the color frequency. For each measured color; Red, green and blue frequencies are individually sampled sequentially using the sensor's special programmable filter. Sensor Output is scaled-down and multiplied by 0.2 due to GPIO pins latency and light frequencies sampled 20 times for Red, green and blue color separately in each reading.

Optimal sampling period for each color of the RGB triplet is approximated successively using the procedure shown in Figure 2, higher efficiency would be achieved by adopting this method.

In order to maximize the accuracy, a calibration phase is performed at the beginning of each session. Using this technique, the adverse effects of environment light on color measurement will be minimized. In the calibration step, black and white color frequencies are measured as the reference frequencies, and each color frequency is converted to the RGB triplet format subsequently using formula 1.

$$RGB = 255 \times (f_{sampled} - f_{black})/(f_{white} - f_{black}) \quad (1)$$

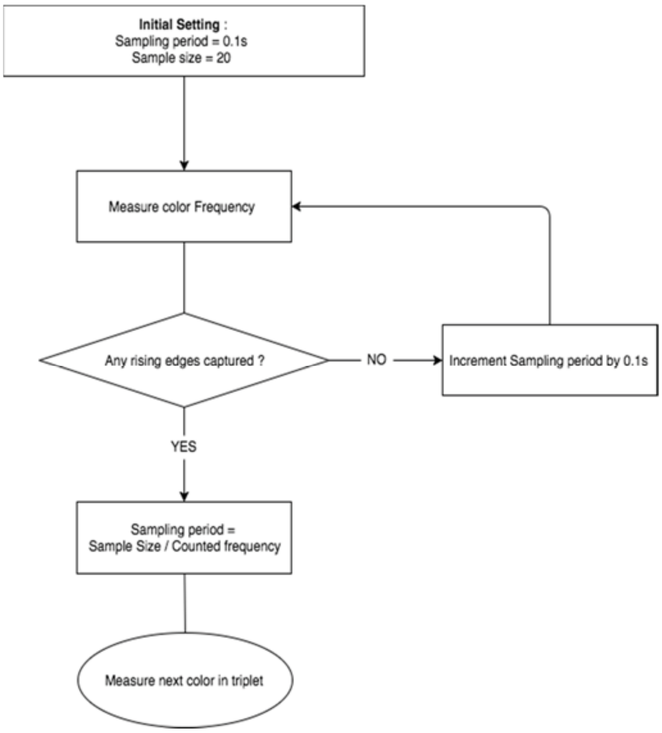


Figure 2. Procedure for calculating the optimal sampling period

- ***Machine-to-Machine Communication***

As mentioned before, one of the major processes in our IoT-based system is transmitting sensor data to the web server through a cloud communication protocol. Since delay plays a significant role in user experience quality and is concerning for real-time responses in our application, a lightweight fast communication method was needed. To fulfill this aim, MQTT protocol is used for communication between the embedded system and web server. The mentioned protocol is a lightweight publish-subscribe messaging transport, which is widely used in IoT systems and wireless sensor networks. A key component of this protocol is MQTT broker which is in charge of dispatching published messages to the subscribers. In our case we used the commercially available hosted message broker "Cloud MQTT" [www.cloudmqtt.com]. Using this method, there are three Quality of service (QoS) options available for published messages: Fire-and-forget (QoS = 0), at-least-once (QoS = 1) and exactly-once (QoS = 2). As mentioned before, latency plays a significant role in our case thus QoS was set to 0 which is the fastest mode with maximized throughput and minimized reliability. In this way, RGB color data is sent using the described method periodically with the frequency of 1 Hz.

- ***Web Application***

A web application was designed for presentation of educational animations and videos to the learners. On the client side, a web page containing instructive notes and videos was designed. Looking to our target experimental population, the content and user interface are designed in a way to be appealing to youngsters. The appropriate files are fetched from the server with a periodical ajax call with 1 second time intervals. On the server-side, we subscribe to the mentioned MQTT message broker, and the RGB values of the current color are available for further process. In later steps, a procedure is needed to match the received RGB with the closest predefined color name. For this purpose, we used CSS's default named colors; as described in algorithm 1, all Euclidean distances from each CSS color is calculated and closest distance is returned as the color name. Since some of the obtained colors might not be distinguishable in real-world objects, later on, colors are grouped into larger categories and for each category, the related animation is returned to client-side. The pseudo code of color matching algorithm is presented in Figure 3.

---

Algorithm 1 : MatchColor (reqColor)

---

Input: reqColor, RGB triplet of requested color;
Output: Name of the closest color that matches the requested color;
minDistance = +inf
**foreach** colorname c cssWebColors() **do**
    redDistance = (c.red – reqColor.red) ^ 2
    greenDistance = (c.green – reqColor.green) ^ 2
    blueDistance = (c.blue – reqColor.blue) ^ 2
    totDistance = redDistance + greenDistance + blueDistance
    **if** totDistance < minDistance **then**
        minDsitance = totDistance
        res = c.name
**return** c.name

Figure3. The pseudo code of matching color algorithm

## IV. Experimental Results

As mentioned earlier, we intended to demonstrate how effective and practical kids' learning can be, on account of our proposed system. For this purpose, we designed an interesting and colorful book, suitable for youngsters, which covers the most common colors in the spectrum, as the standard source. In addition, the related multimedia contents to be augmented on web application have also been designed in a way to be attractive, interactive and repetitive to facilitate the learning process. In the conducted case, Spanish language was chosen due to experimental reasons: In order to be able to correctly evaluate the impact of the proposed system on learning procedure, we chose a language that the statistical population had the least information about, to the best of our knowledge. Nevertheless, the presented system can be customized easily, in order to support teaching in any desired language.

### *A. Influence on learning*

To evaluate the effectiveness of the proposed system on learning performance, a paired t test was conducted on a population of 35 girls between the ages of 10 and 12, picked randomly among "Manzoumeh Kherad" institute's primary school students. First, we picked 4 colors (Blue, Red, Yellow, Green) to work with. Then, each student was asked whether she already knew any of the colors in Spanish language. After that, they were asked to use the system to discover and learn each color on their own by taking in the correspondent multimedia content. After ten minutes, each student was tested again with exact same 4 color quiz. Their pre-test and post-test scores were used to determine whether their knowledge improvement was statistically significant or not. Each set of scores (before and after test) were sampled separately. It is also important to note that participants' learning duration was an uncontrolled variable in our experimental design, but we have considered a threshold of 10 minutes for each person to use the system. Table 1 shows the statistical results on comparison of Pre-Test and Post-Test scores.

Comparing the results of pre-test and post-test scores presented in Table 1, indicates that participants performed tremendously better on post-test than pre-test; considering mean for pre-test and post-test values which has been changed from 0.057 to 3.029, and also the three times mutation of median of the scores, truly confirms it. The standard deviation of pre-test and post-test determines greater spread in the data after interacting with the system. That may happen because of the learner's enthusiasm to learn more colors in Spanish language and also their unfamiliarity with Spanish words.

It is also to be noted that to evaluate the learning performance, paired t-test is applied. Table 2 shows the results.

Results of paired t-test revealed that participant's score means were 3.11 with the standard deviation of 0.73 while pre-test scores had a mean of 0.057 with the standard deviation of 0.338. Since no major outliers were detected and according to SD values in both pre-test and post-test results, interpretation of paired t- test is tended to be reliable and flawless in case of our experiment. The most striking result emerging from the data is that the participants' score was increased by 2.97 points after using the system, which is a 74% improvement in score. Since obtained P-Value is 1.27E-22 which is less than 0.05, it can be concluded that there is a statistically significant difference between the means of participants' score before and after using our system.

Table1. Statistical Results on Pre-Test and Post-Test Scores

| | Pre-Test Scores | | | | | Post-Test Scores | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Students | M | Mdn | SD | Min | Max | M | Mdn | SD | Min | Max |
| | 0.057 | 0 | 0.338 | 0 | 2 | 3.029 | 3 | 0.747 | 2 | 4 |

Table2. Paired T-Test Results

| **t-Test: Paired Two Sample for Means** | | |
|---|---|---|
| | Variable 1 | Variable 2 |
| Mean | 0.057142857 | 3.028571429 |
| Variance | 0.114285714 | 0.557983193 |
| Observations | 35 | 35 |
| Pearson Correlation | 0.226284819 | |
| Hypothesized Mean Difference | 0 | |
| df | 34 | |
| t Stat | -23.53362117 | |
| P(T<=t) one-tail | 6.33903E-23 | |
| t Critical one-tail | 1.690924198 | |
| P(T<=t) two-tail | 1.26781E-22 | |
| t Critical two-tail | 2.032244498 | |

### *B. Color Measurement Precision*

It is plausible that a number of limitations may have influenced the obtained results. The sensor does not always translate the color into RGB equivalent accurately. As explained in proposed approach, to mitigate the measuring errors' effect on results, each color has an accepting area comparing to the exact RGB equivalent, and each transmitted number included in this domain would be accepted as the corresponding color. We want our proposed system to be usable under any light condition, so we attempted to calculate the average measurement error of the obtained results from various circumstances.

For this purpose, an experiment was conducted to examine accuracy of red, green and blue values measured. We selected five points to equally divide 0 to 255 range (0, 63, 127, 190, 255); then scanned the colors they represented in both day light and artificial light. The color real values' dispersion, relative to the expected values, is demonstrated in Figure 4.

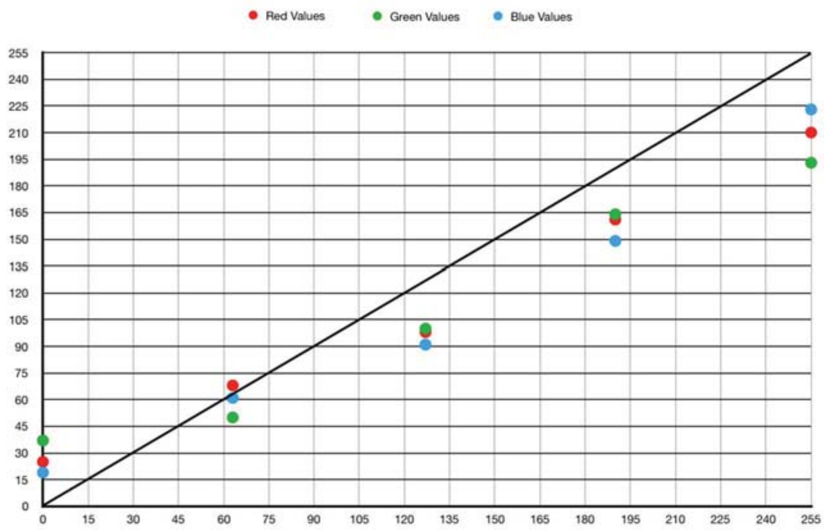


Figure 4. Colors' real values' dispersion relative to y=x

When working with colors, we require a more tangible analysis to be able to properly measure the difference in visual perception. To do so, we calculated the "Delta E" color difference values for 10 sample colors. "Delta E", is a metric based on three-dimensional l*a*b color space, to understand how the human eye perceives color differences. The calculated "Delta E" values are presented in Table 3. Delta E value can change from 0 to 100. Accordingly, Delta E less than or equal to 1 means that the color difference is not perceptible by human eye, and Delta E equal to 100 means that the colors are the exact opposite. The obtained average Delta E is 16.780 which means colors are similar but the difference is recognizable for human eye.

Table3 and Figure5 presents the Delta E values and also visual comparison of actual RGB and the RGB received from the sensors.

Table 3. Delta E values

| ΔE | Actual Values | | | Measured Values | | |
|---|---|---|---|---|---|---|
| | R | G | B | R | G | B |
| **3.3961** | 0 | 0 | 0 | 0 | 5 | 12 |
| **34.951** | 255 | 0 | 0 | 210 | 37 | 52 |
| **29.3914** | 0 | 255 | 0 | 25 | 198 | 18 |
| **37.5663** | 0 | 0 | 255 | 22 | 60 | 23 |
| **12.515** | 127 | 127 | 127 | 98 | 100 | 91 |
| **8.0243** | 255 | 255 | 255 | 255 | 243 | 255 |
| **22.6** | 63 | 255 | 255 | 68 | 204 | 223 |
| **7.2061** | 0 | 127 | 63 | 14 | 112 | 53 |
| **7.9922** | 255 | 127 | 190 | 248 | 108 | 168 |
| **4.1634** | 58 | 255 | 190 | 52 | 243 | 179 |

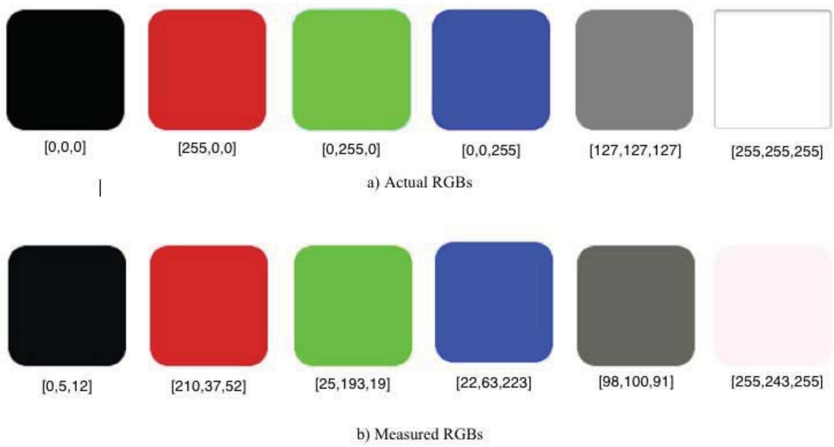


Figure 5. The actual and measured RGBs

## V. Conclusion and Future Prospects

Presuming practical interest in AR-based and interactive learning, this work has focused on implementing such a system based on IoT principles, targeting younger audiences. The obtained results show that learning outcome can be improved significantly through interacting with the proposed system. This work revealed how a low-cost color sensor can be employed to make a learning system with augmented reality capabilities for kids and proved that our proposed system can be practical and useful improving kids' knowledge in a self-instructional and interactive manner.

The achieved results from paired t-test reveal the significant learning performance from pre-test to post-test, which is about three times mutation in mean and median.

Being able to completely evade measurement error is logically impossible. The error in our case being the fact that the sensor does not always accurately translate the color into RGB equivalent. To overcome this problem, we employed "Delta E" metric to better understand how the human eye perceives color difference. The obtained average Delta E is 16.780, which means colors are similar but the difference is perceptible for human eye. As explained in proposed approach, to mitigate the measuring errors' effect on results, each color has an accepting area comparing to the exact RGB equivalent, and each transmitted number included in this domain would be accepted as the corresponding color. Therefore, our work won't be applicable where colors are too similar especially with Delta E values less than 30.

The achieved results are promising; however, they should be validated by a larger sample size. Also, for a better study on the proposed system's enhancing effects on learning in comparison to conventional methods, it is recommended that further studies employ t test : testing a group of users after being taught using conventional methods and then testing another group who utilized the proposed system. Despite the significant score improvements, a more careful analysis should be done in future researches considering the knowledge around human memory functionality [27] regarding the fact that some important factors like number of questions and the duration of learning can actually affect the test results.

Our research could be a useful aid for kids with learning disorders like autism, helping them develop social and communication skills while interacting with a smart device instead of an instructor. Also, future work can focus on making the web application more interactive. For example, by taking quizzes at the end of each learning chapter or other innovative ideas which can make the application more interactive and appealing. Our method has the potential to be used in teaching other materials using each color as a unique code for matching shapes, objects and etc. to appropriate related educational content. For this purpose, further works should be done on enhancing color measurement accuracy.

## Acknowledgment

We would like to appreciate the director, principle, teachers and students of "Manzoumeh Kherad" institute's primary school who have permitted and participated in the process of testing our system in their school. Also we are grateful to Mr. Ehsan Mousavi Madani for his valuable suggestions.

## References

[1] S. Madakam, R. Ramaswamy and S. Tripathi, "Internet of Things (IoT): A Literature Review," *Journal of Computer and Communications,* vol. 3, pp. 164-173, 2015.

[2] L. Shams and A. R. Seitz, "Benefits of multisensory learning," *Trends in Cognitive Sciences,* vol. 12, no. 11, pp. 411-417, 2008.

[3] A. Sula and E. Spaho, "Using Assistive Technologies in Autism Care Centers to Support Children Develop Communication and Language Skills. A Case Study: Albania," *Academic Journal of Interdisciplinary Studies,* vol. 3, no. 1, pp. 203-212, 2014.

[4] J. Go´meza, J. F. Hueteb, O. Hoyosa, L. Perezc and D. Grigorid, "Interaction System Based on Internet of Things as Support for Education," *Procedia Computer Science,* vol. 21, pp. 132-139, 2013.

[5] A. Uzelac, N. Gligoric and S. Krco, "A comprehensive study of parameters in physical environment that impact students' focus during lecture using Internet of Things," *Computers in Human Behavior,* vol. 53, pp. 427-434, 2015.

[6] S. Charmonman, P. Mongkhonvanit, V. Ngoc Dieu and N. Van der Linden, "Applications of Internet of Things in E-Learning," in *The twelfth International Confrence on eLearning for Knowlede-Based Society*, Thailand, 2015.

[7] H. Kauffmann, D. Schmalsteg, M. Wagner, "Construct3D: A Virtual Reality Application for Mathematics and Geometry Education", Education and Information Technologies Journal, Vol.5, No.4, 2000, pp.263-276

[8] H. Matsuda, Y. Shindo, " Estimation of e-Education system using Virtual Exploratory Learning", Procedia Computer Science, Vol. 35, 2014, pp.757-765.

[9] Carlos Efrén Mora Luis, Reyes Carrau Mellado, Beatriz Añorbe Díaz, "PBL Methodologies with Embedded Augmented Reality in Higher Maritime Education: Augmented Project Definitions for Chemistry Practices", Procedia Computer Science, Vol. 25, 2013, pp.402 – 405.

[10] T.-Y. Liu, T.-H. Tan and Y.-L. Chu, "2D Barcode and Augmented Reality Supported English Learning System," in *6th IEEE/ACIS International Conference on Computer and Information Science*, Taipei, 2007.

[11] F. Mohamed Adnan Khan and M. Masood, "Potential of Interactive Multimedia Learning Courseware using three different strategies in the learning of biology for Matriculation students in Malaysia," *Procedia - Social and Behavioral Sciences,* vol. 116, p. 2521 – 2525, 2014.

[12] H. Swensen, "POTENTIAL OF AUGMENTED REALITY IN SCIENCES EDUCATION A LITERATURE REVIEW," in *Proceedings of ICERI2016 Conference*, Seville, 2016.

[13] V. K.P, A. Chowdhury, R. Kambam and V. Muralidharan, "Augmented Reality based Interactive Text Book An Assistive Technology for Students with Learning Disability," in *XV Symposium on Virtual and Augmented Reality*, Hyderabad, 2013.

[14] M. Billinghurst, H. Kato and I. Poupyrev, "The MagicBook- Moving Seamlessly between Reality and Virtuality," *IEEE Computer Graphics and Applications,* vol. 21, no. 3, pp. 6-8, 2001.

[15] M. Tayefeh Mahmoudi, S. Mojtahedi and S. Shams, "AR-based value-added visualization of infographic for enhancing learning performance," *Comput Appl Eng Educ,* pp. 1-15, 2017.

[16] S. Hwa Lee, J. Choi and J.-I. Park, "Interactive E-Learning System Using Pattern Recognition and Augmented Reality," *Transactions on Consumer Electronics,* vol. 55, no. 2, pp. 883-890, 2009.

[17] W.F.F.Yahya, N.M.M.Noor, M.P.Hamzah, M.N.Hassan, N.F.A. Mamat., M.A.S.M. Rifin (2015) Integrating e-Learning with Radio Frequency Identification (RFID) for Learning Disabilities: A Preliminary Study. In: Sulaiman H., Othman M., Othman M., Rahim Y., Pee N. (eds) Advanced Computer and Communication Engineering Technology. Lecture Notes in Electrical Engineering, vol 315. Springer, Cham.

[18] C. V. Ramdas, N. Parimal, M. Utkarsh, S. Sumit, K.Ramya, B.P.Smitha, "Application of Sensors in Augmented Reality based Interactive Learning Environments," in *Sixth International Conference on Sensing Technology (ICST)*, Bangalore, 2012.

[19] Aline Inc., "Design of a color sensing system to aid the color blind," *IEEE Potentials,* vol. 27, no. 4, 2008.

[20] M. Tayefeh Mahmoudi, K. Badie and M. Valipour, "Assessing the Role of AR-Based Content in Improving Learning Performance Considering Felder- Silverman Learning Style," in *Proceedings of 2015 International Conference on Interactive Collaborative Learning (ICL)*, Florence, 2015.

[21] L.W. Anderson (Ed.), D. R. Krathwohl (Ed.), P.W.Airasian , K.A.Cruikshank, R. E. Mayer, P. R. Pintrich, J. Raths & M.C.Wittrock, (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives (Complete edition). NewYork: Longman.

[22] S.Ghasemi, F.Taghiyareh, M.T.Mahmoudi, “Enhancing Quality of Learning based on Cognitive Levels of Bloom in Blended Learning Environments”, 3rd Conf. on Engineering Education, Tehran, Iran, 2013.

[23] M. Rauschenberger, M.Schrepp, M. Perez-Cota, S.Olschner and J. Thomaschewski, "Efficient Measurement of the User Experience of Interactive Products. How to use the User Experience Questionnaire (UEQ).Example: Spanish Language Version," *International Journal of Artificial Intelligence and Interactive Multimedia,* vol. 2, pp. 39-45, 2013.

[24] . P. Schrepp, "User Experience Questionnaire Handbook," 2015.

[25] J. Gubbia, R. Buyya and S. Marusic, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future Generation Computer Systems,* vol. 29, no. 7, pp. 1645-1660, 2013.

[26] Texas Advanced Optoelectronic Solutions (TAOS), "programmable color light-to-frequency converter," TCS3200 datasheet, Jul. 2009, [Revised Sept. 2017].

[27] A. D. Baddeley, Human Memory: Theory and Practice, Needham Heights, MA: Allyn & Bacon, 1997, pp. 9-26.