ISSN: 2178-7727
DOI: 10.17648/acta.scientiae.v21iss3id5165

Mathboard: An Intelligent Object for use in Educational Activities

Luana Prestes Madrid[a]
Fabiana Lorenzi[a]

[a] Universidade Luterana do Brasil, Curso de Ciência da Computação, Canoas, RS, Brasil.

Received for publication on 16 Apr. 2019. Accepted, after revision, on 29 May 2019.
Assigned editor: Claudia Lisete Oliveira Groenwald.

ABSTRACT

This article presents the development of an educational game, which uses the concepts of board games and internet of things with the purpose of helping children in the learning process. The tool will allow integration between Students and Teachers, which the parties will use for the process of continuous learning, providing information to the teacher about student progress, thus enabling the same to help the student through the administration panel. Problems involving numerical expressions developed by Mathematics teachers were used to validate the proposed game.

Keywords: Learning Objects. Educational game. Internet of things.

Mathboard: um Objeto Inteligente para Auxílio no Aprendizado de Matemática

RESUMO

Este artigo apresenta o desenvolvimento de um jogo educativo, que une os conceitos de jogos e internet das coisas com o intuito de auxiliar alunos no processo de aprendizado. A ferramenta possibilitará uma integração entre Aluno e Professor, onde ambas as partes podem utilizá-la, para um processo contínuo de aprendizado, fornecendo informações ao professor sobre a evolução do aluno no jogo, possibilitando assim que o mesmo auxilie o aluno no jogo através da ferramenta. Para validação do jogo proposto foram utilizados problemas que envolvem expressões numéricas trabalhados por professores da área da Matemática.

Palavras-chave: Objeto de Aprendizagem. Internet das Coisas. Jogo Educacional.

INTRODUCTION

The technology is already part of the everyday life of many of the students, the use of cell phones, computers, tablets and other devices. These items can also be used as beneficial at school since there are already applications available to aid in education. According to (Camas, 2014), new technologies must be part of everyday life as is the book, the blackboard and chalk.

The use of technology in the world of education is intensifying more and more. “We can believe that computing is an incredible resource in the learning process. Through it,

Corresponding author: Fabiana Lorenzi. E-mail: fabilorenzi@gmail.com

it is possible to carry out actions, develop ideas and build knowledge that, in a traditional classroom, may not have been developed" (Morin et al., 2002). Learning objects have been used by several teachers as ways to aid in student learning. A learning object is any type of tool, digital or non-digital, that can be used during learning supported by Wiley (2002) technology.

This work presents the Mathboard, a learning object (configurable by the teacher) that aims to practice activities so that the student can learn and/or fix the content in a playful way. This paper presents the main concepts necessary to understand the presented work, the learning object design, the techniques used in the implementation of the Mathboard and the tests performed and results achieved.

BACKGROUND

This section presents the main fundamental concepts for understanding the work. The learning object definitions are initially presented. Then, we present the term IoT (Internet of Things) and its solutions. Finally, the definitions and considerations about gamification in education are presented.

Learning Object

Learning Object is a teaching unit that can be reusable. A learning object, described by the Institute of Electrical and Electronics Engineers – IEEE (2002), is defined by digital resources or not, where they can be used for education, training or learning.

Repetition and understanding are not enough for a person to learn a particular concept; it is necessary to provide circumstances where he has the option of coordinating actions and making choices. Therefore, the higher the number of interactions an object can provide, the better the learning of who is operating (Araujo, 2017).

According to (Behar et al., 2007), a learning object has as main characteristic the possibility of reuse of its resources in different contexts. In addition, they are independent and can be used as modules of specific or complete content.

There are countless researches where the teaching strategies and the way of learning mathematics through games are being approached. Through these, learning becomes more inspiring and interesting for students and teachers (Atrapason, 2011).

According to Araujo (2017), the learning object should not have the purpose of merely doing, which is, arriving at a correct answer, but a job with intention, so that it is possible to present an adequate environment for transformation. It is essential to design activities rich in challenges for those involved in the learning object.

Internet of Things

The Internet of Things (IoT) has emerged with the evolution of several areas, such as microelectronics, embedded systems, communication and sensing. IoT is an extension of the Internet, which provides daily objects with a connection to the network (Santos et al., 2016).

Initially, the evolution came with the connection of two computers, and later, with the creation of the World Wide Web (www), it was possible to connect many computers. The mobile internet came about, allowing the connection of mobile devices with the internet, and then people were inserted in this ubiquitously connected environment. Finally, there is IoT, linking all the objects with the internet. Figure 1 shows the evolution of IoT in five phases.

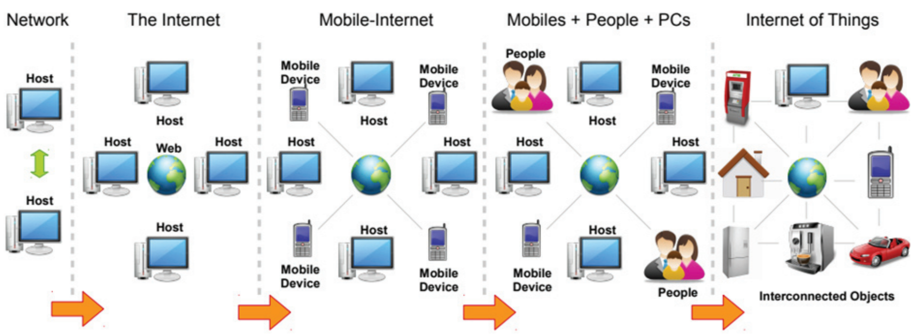

Figure 1. Evolution of IOT (Perera et al., 2014).

The goal of IoT is to establish an interaction between intelligent objects through the Internet, dividing the operation into steps, being the unique identification.

According to (Santos et al. 2016), intelligent objects have a summarised architecture composed of four units. Figure 2 shows the architecture of the devices.

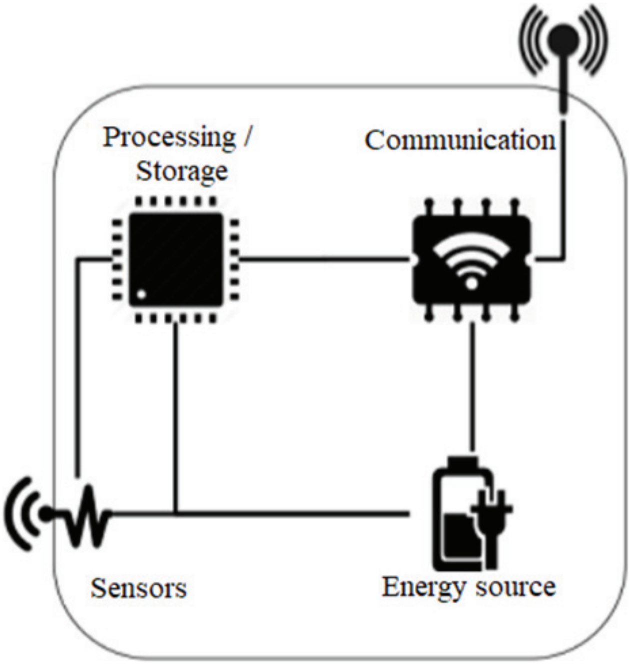

Figure 2. Device architecture (Santos et al., 2016).

As shown in Figure 2, the devices have an internal storage memory, a micro-controller and a converter for receiving signals from the sensors. The CPUs do not have high computational power; usually, there is a flash memory, where it is possible to store the data logs, for example. Communication consists of at least one wireless transmission channel. The power source is responsible for supplying energy to the components of the intelligent object, and the sensors monitor the environment where the object is located.

According to Shenoy (2018), with sensor technology, it is possible to obtain object and equipment data to understand what is happening in real time as they provide detailed information. With this, it is possible to determine needs and generate accurate evidence.

Gamification in Education

The ubiquitous use of technologies as tools in people's daily lives, including younger students, has already become a routine aspect. The demotivation of students in school is a factor analysed in different levels of schooling and can be considered a consequence of the inadequacy of traditional patterns (Brito & Madeira, 2017).

A proposal to assist in education is the use of elements and mechanisms of games aggregated to the computational environment, with a view to make it more attractive to students and encourage their use. This approach is known as gamification (Seaborn & Fels, 2014).

The gamification is the use of fundamentals for an idealisation of games in non-game contexts, in order to increase the commitment of the users (Dominguez et al., 2013). With the gamification and the idea of the ludic context, one has the ability to generate among the players, a level of engagement similar to what is obtained in a video game (Deterding et al., 2014).

According to (Lee & Hammer, 2011), the purpose is not to teach with games, but to use their foundations as a way of encouraging students' involvement in activities. Studies show that gamification has excellent ability to benefit users' knowledge and engagement in a variety of sectors, including educational environments. However, it is essential to emphasise that the role of teachers is of paramount importance in order for this process to be carried out effectively (Amriani et al., 2013).

Related Work

In (Cruz et al., 2017), authors present an educational game with the intention of raising awareness and educating the population about the ecosystem. The game consists of dissemination, education and preservation of the caatinga ecosystem. IoT is used in this game in conjunction with data science in data collection and analysis. Users can report possible cases of environmental crime, where it is possible to attach photos and report testimonials to be sent to the responsible authorities. In addition, it provides the creation of a database of species categorisation for researchers, serving as information and catalogues, and is able to help find new species. The result of crossing these data is illustrated in charts and tables. All the features offered by the system can be used via both web and application.

Nakazoni (2016) presents a learning object that works with specific mathematical contents in a collaborative way. The evaluations and exercises are inserted in an environment, being presented through questions of multiple choices and discursive. Participants are able to communicate through additional tools to resolve issues. In the evaluations, these communication resources are not used, and each participant performs the test individually. We can see that when individuals work together, the information becomes learning.

PROJECT

This section presents the descriptive of Mathboard, its functional, structural and operational parts.

The Mathboard goal is to help students in the learning process. It is an educational game using IoT, where the student is invited by the teacher to work on mathematical expressions (initially only addition, subtraction, multiplication and division operations). The game works via wi-fi, characterised by web pages, so that the student can play, and that it is possible the accompaniment, aid, and administration of the teacher.

The game consists of two physical objects (an actuator and a board), which communicate and a web interface. Given a particular numerical expression, the student must move the actuator on the board, indicating the correct operator to solve the expression indicated in the question.

The Mathboard has a teacher module, where it creates the activities that will be carried out by the students. It can also access students' knowledge evolution by having access to a report of each student's actions during the game. This allows the teacher to visualise which topic the student has the most difficulty. In addition, the teacher can insert response tips so that the student does not lose his motivation or his engagement in the learning process.

Survey of Technical Needs

In this stage, the collection of technical information was carried out, such as the definition of services to be used, based on specific procedures to be achieved. The search for strategic points of commands and manipulations of sensors in the prototypes were defined through the micro-controllers. The programming was done through the software Arduino.

Mathboard consists of web pages, using the Java languages with the framework JHipster for back-end and JavaScript with the framework React for the frontend. The exchange of messages between the prototypes and interface is done through MQTT and WebSocket protocols. For this, an AWS (Amazon Web Services) server was used in an EC2 machine to upload the Mosquitto service, which will provide a broker, where the connections were opened for real-time message sending by socket to the front-end through port 9001 and backend by MQTT through port 1883. The game information to be saved is stored in the relational database.

Actuator Prototyping

The assembly of the actuator hardware was done under a lightweight board, and a rigid sheet was used to create the housing. This object was created with the following electronic components:

- 1 *microcontroller NodeMCU ESP8266*;
- 2 motors of direct current;

- Wheel 68mm for chassis;
- 1 module *dual h-bridge motor driver L298N*;
- 3 *high brightness LEDs*.
- 2 batteries 9v;
- 1 170tp *Protoboard*;
- 1 Light switch *mrs-101-2c.*

The electrical schematic of the actuator can be seen in Figure 3.

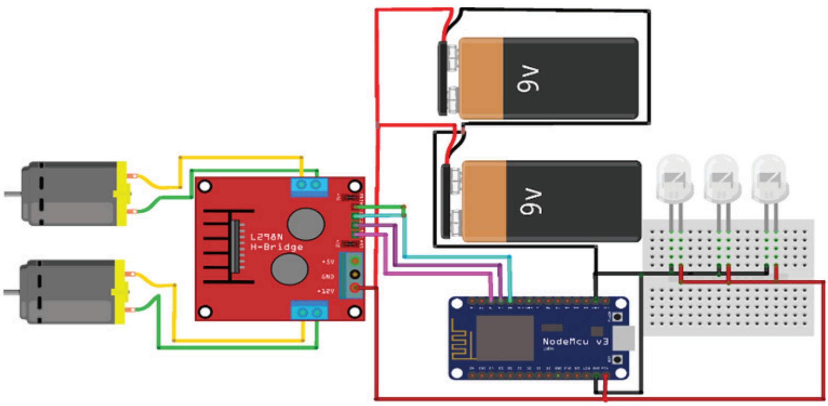

Figure 3. An electrical schematic of the actuator.

Prototyping Board

The board circuit was created with a rigid sheet, pre-marked with luminosity sensors (LDR). These sensors are fixed with the mathematical operators (addition, subtraction, multiplication and division). This object has the following electronic components:

- 1 *microcontroller* NodeMCU ESP8266;
- 1 analogue multiplexer 74HC4051 required to extend the number of analogue ports since the board is composed of 4 analogue sensors and the NodeMCU has only 1 input;
- 1 green LED to control the operation of the tray;
- 5 resistors being 4 of 10kΩ to limit the electric current of the light sensors, and a 200Ω resistor for the led;
- 1 battery 9v;
- 1 light switch *mrs-101-2c.*

The electrical schematic of the board can be seen in Figure 4.

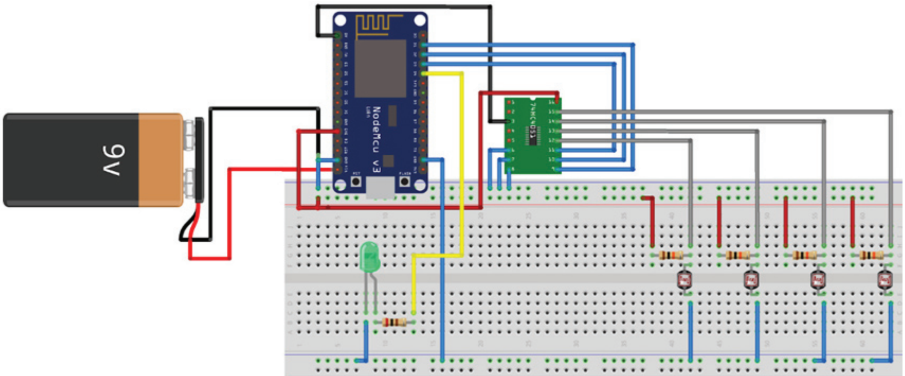

Figure 4. An electrical schematic of the board.

Arduino Software

The Arduino software was used to program the Arduino used in the prototypes (actuator and board). In this stage, the programming logic used in the microcontrollers was defined, so it was possible to carry out the manipulation of electronic components and communication with the server.

In order to start the programming, it was necessary to use ESP8266WiFi libraries, to use the wi-fi and PubSubClient to exchange messages between the services. It was also necessary to configure the MQTT id and topic settings for publication and IP listener and MQTT broker port. Then the software initialises and connects to the wi-fi network and the desired broker.

Actuator

The actuator keeps listening to the messages sent to the broker and executes the commands received for 1 second. The web application will send messages to the broker, for example, when the "F" message is identified. The actuator then will connect to the two motors during the set time and moves it forward. When the "D" message is received, only the right motor is turned on, causing the actuator to move to the right, receiving "E", only the left motor is driven, thus moving it to the left side, and when the message "P" is found, the polarity of the motors is inverted and both are switched on, causing the actuator to move in the reverse direction, i.e., backwards.

The Board

The board is composed of LDR sensors, in which it works with light detection capability, with maximum brightness 0 (extremely light) and minimum 1024 (dark). For the sensor drive administration, a control variable was created.

The board publishes the messages in the broker; by default, the publication is a question mark (?). When the LDR sensor reaches a brightness lower than 800, an operation message is published in the broker. To monitor the board, we added a green led and when it turns on it means that the board is on, and when it starts flashing, it means that the connections with the wi-fi and broker are on.

Webpages

The web pages were created responsively, that is, they adapt to the size of the screen used, being it a cell phone, tablet or computer.

Since the goal of the student is the gameplay, in order to move the actuator to the alternative, a friendly interface was developed for the student.

DEVELOPMENT OF *MATHBOARD*

This section presents Mathboard development and its main components.

Creating Physical Objects

To make the Mathboard iterative, two physical objects were created, which are described below. Mathematics teachers were interviewed to obtain suggestions on the size and style of the board, which were used in the creation of the actuator and the board.

The actuator is an object with wheels that move in 360°, according to the movements made by the student in the web interface. These movements can be right, left, up, or down. The student indicates the movement in the web interface that transmits to the actuator. The final prototype of the actuator can be seen in Figure 5.

Figure 5. The final version of the actuator.

The board is a pre-marked surface with luminosity sensors. These sensors have the correct markings of the mathematical operators. These signals are sent to the web interface according to the drive, through the light of the actuator. The actuator must be moved by the student on the mathematical operator necessary to solve the expression indicated in the question. The final version of the board can be seen in Figure 6.

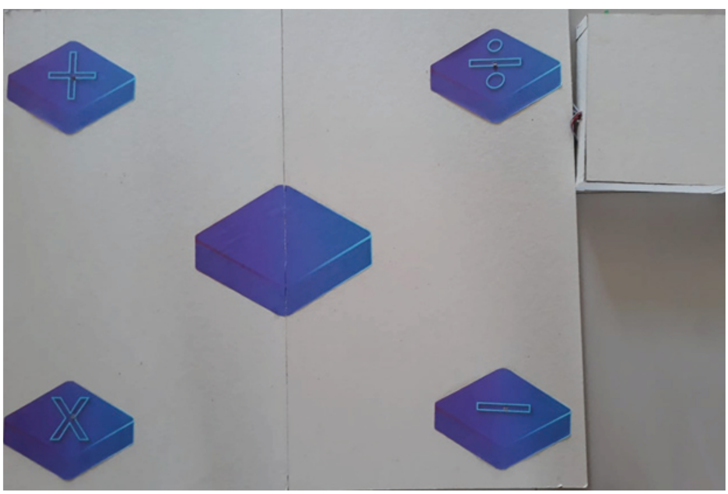

Figure 6. The final version of the board.

Creation of Webpages

The pages have been created so that the teacher can manage the game environment for the student to practice the activities. The web pages have been divided into two sections, which will be detailed below.

Teacher Module

The administration environment allows the teacher to register activities, classes, students and monitor performance. In this environment, the teacher will perform the settings of these features. The teacher admin is composed of a unique login.

The teacher has to register the class(es), the student(s) and the questions that will be associated with a class. These instructions are presented to the teacher on the homepage that appears shortly after the login. The class listing page can be seen in Figure 7.

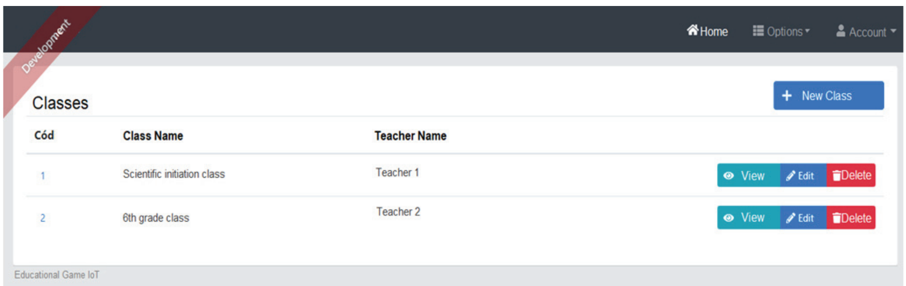

Figure 7. List of Classes Page.

The students' register is necessary for his/her login to start the game. In addition, the questions displayed in the student's environment are always associated with the class defined in this register.

The teacher needs to add the questions in the form of a mathematical expression, indicating the place of the operators through question marks. The system will perform the calculation of the expression registered according to all possibilities of operators in the response.

The teacher has access to a game report, where you s/he can follow the performance of each student during the game. This report has the number of errors that shows the number of times the student missed the question; if the student asked for help on each question; the name of the student who started the game and the information related to the question number and the student-related Class.

Student Interface

As the game depends on the actuator and the board, only one student play at a time. The first screen has the login where the student must fill the username and password (previously created by the teacher).

In order to move the actuator to the operator corresponding to the answer, the student may choose one of the four buttons (the directional arrows) that represent front, back, right and left.

The student may ask help in the game, and a tip (that was added by the teacher) is presented.

After completing all the operators of the question, the student must click on the Validate button, where the game checks (automatically) if the answer is correct. It is essential to point out that generally in educational games, the teacher registers the correct answer. In Mathboard, however, the game calculates the correct response of the expressions, avoiding the need for the teacher to register.

If the answer is incorrect, a message is shown to the student try again. When the student hits the question, a congratulations message is displayed, and the next question is presented. Figure 8 shows an example of the game being played by a student.

Figure 8. Example of the game.

EXPERIMENTS AND RESULTS

This section presents the tests performed and the results obtained. The tests were performed in two different steps. The first test was performed with mathematics teachers, where they added the expressions to be used in the game.

Since, in this research, the names of the participants were replaced by numbers to avoid their identifications, a prior ethical evaluation was not requested by the CEP / CONEP System of the project in which the present work is carried out, according to Art 1º, of Resolution n. 510, dated April 7, 2016, from the National Health Council: "They will not be registered or evaluated by the CEP / CONEP system: a research that aims to deepen theoretical situations that emerge spontaneously and confidentially in professional practice, provided they do not reveal data that can identify the subject "(VII).

Experiments with Teachers

This first version of Mathboard was developed to work exclusively with numeric expressions, inserted by the teachers.

The teacher must always insert the expression with an interrogation mark representing the operator and the final result of the expression. The student evaluates the expression and answers the operator in the expression (or operators, if the expression has more than one operator). For example, the teacher can insert 2? 2 = 4 or 2? 2? 2 = 8 and the student should evaluate and inform the corresponding operators.

In the first test performed with the teachers, they were invited to use the teacher module, adding some numerical expressions. They were then invited to play (as if they were students), in order to assess the student's vision.

After this first experiment, some improvements were made, such as:

- Add a congratulations message to the student when the answer is correct;
- The source of question presentation was increased;
- In the game report, the number of errors column should start at 0;
- The signs "+" and "*" were adjusted because on the board they were similar;

Experiments with Students

At this stage, Mathboard was applied in the classroom to two distinct classes: a class of undergraduate students and a 6th-grade class. The sample of validation data can be seen below.

The teacher module was used by two tutors, being: a graduate teacher and an elementary school teacher; both carried out the registration of class, students and questions.

The undergraduate teacher added 2 students for the validation of the game, being: Undergraduate student 1 and Undergraduate student 2. The teacher registered 10 questions for the students of this class to play.

Analysing the undergraduate student's gameplay report 2, we can see that he did not hit question 4, missed question 5 and 6 twice, and asked for help only in question 8.

In the undergraduate student's gameplay report 1, we see that the student did not hit question 3, and missed question 5 twice, and asked for help in questions 6 and 8.

The elementary school teacher registered 15 students (6^{th}-grade students) for the validation of the game, known here as Elementary students 1, Elementary students 2, Elementary students 3 to Elementary students 15. Only three questions have been registered by the tutor, which can be seen in Figure 9.

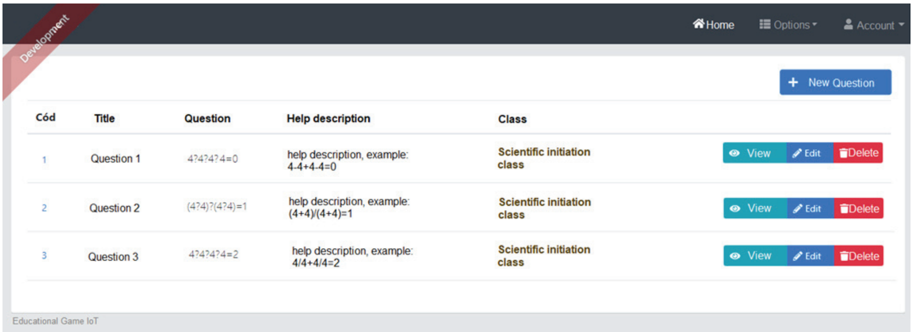

Figure 9. Example of questions.

Due to the large amount of registration, only three reports were analysed. In the report of Elementary School student 1, it was seen that he did not hit question 3, and asked for help in questions 2 and 3.

Report on Elementary School 2 shows that the student did not hit questions 2 and 3 and asked for help in question 3. Student 3 did not miss a question and asked for help only in question 3

The test achievements were of great importance for the final operation of the Mathboard because relevant information was gathered, such as the need to add one more battery to the actuator, so that it can support all the electronic components for a more extended period of time. In the first tests with the teachers, requirements of improvements of high relevance were raised.

The improvement tips performed contributed to arrive at a satisfactory result. In the final validation stages, the teacher was surprised and said that she appreciated all the functions that were created, which will add value to students learning in mathematics disciplines in which they work with the numerical expressions.

The opinion of the undergraduate students who practised the activities was positive, they found "the game very interesting and fun," that "the way of approaching the content is technological, and that the students would possibly like it as well."

In the validation with the elementary students, we saw that they loved the idea of controlling a robot to practice mathematical activities. It was not possible to yet to measure how much the game aided in the learning process, but we want to carry out new experiments with the classes, with directed activities, so that it would be possible to prove this hypothesis.

CONCLUSIONS AND FUTURE WORK

This work involves concepts of a learning object provided by IoT technology, which offers a game that covers concepts of interactivity and play. Mathboard is an educational game that, through wireless communication, intends to increase students' interest in practising the school exercises in the classroom.

One of the purposes of this learning object is to evaluate students' knowledge evolution and to pass on to the teacher all the student's actions during the game, so that the teacher can see where the student has the most difficulty, for example.

We hope that the possibility of the teacher accompanying the students throughout the game in a virtual way, and with the help available during the game can help in the learning process. Often a student becomes "stuck" in a specific exercise, cannot move forward, and loses interest in the activity so that the student's motivation can be instigated.

As future work, it is intended to make the object adaptable to any discipline of education, aiming at the alteration of mathematical expressions, by mechanisms configurable by the teacher, thus enabling the sending of any expectation of a response.

Another interesting proposal is the adaptation of the Mathboard for the visually impaired, creating the answers alternatives and identifying the actuator in braille. Also, it will be necessary to use the library *JavaScriptResponsiveVoice* so that the issue of the application is read to the student.

AUTHORS' CONTRIBUTION STATEMENTS

F.L. oversaw the project. F.L. conceived for the idea presented. L.M. developed the theory. L.M. adapted the methodology to this context, created the models, executed the activities and collected the data. L.M. and F.L. analysed the data. Both authors discussed the results and contributed to the final version of the manuscript.

REFERENCES

Alves, Tiago. (2015) *Explorando a Internet das Coisas Sociais Utilizando NFC em um Campus Universitário*. (81 f). Dissertação (Mestrado em Computação Aplicada) – Universidade do Vale do Rio dos Sinos, São Leopoldo.

Amriani, A., Aji, A. F., Utomo, A. Y., & Junus, K. M. (2013, October). An empirical study of gamification impact on e-Learning environment. In *Proceedings of 2013 3rd International Conference on Computer Science and Network Technology* (pp.265-269). IEEE.

Araujo, A. (2017, October). Experiências lógico-matemática: um objeto de aprendizagem de uso integrado de recursos manipulativos digitais. In proceedings of the *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação – SBIE)* (Vol. 28, No. 1, p.546).

Behar, P. A., Bernardi, M., & Souza, A. P. F. D. C. (2007). Objeto de Aprendizagem integrado a uma plataforma de educação à distância: a aplicação do COMVIA na UFRGS. *RENOTE: Revista Novas Tecnologias na Educação [recurso eletrônico]. Porto Alegre, RS*.

Brito, A., & Madeira, C. (2017, October). Metodologias gamificadas para a educação: uma revisão sistemática. In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação – SBIE)* (Vol. 28, No. 1, p.133).

Camas, Nuria (2014). *Novas tecnologias facilitam a aprendizagem escolar*,. Disponível em: <http://www.brasil.gov.br/educacao/2014/07/novas-tecnologias-facilitam-aprendizagem-escolar> Acesso em: fev. 2018.

Cruz-Júnior, G. C., Nascimento, R., Cysneiros, G., Alves, G., & Santos, E. (2017, October). Internet das Coisas, Games e Data Science a serviço da conscientização e preservação da Caatinga. In proceedings of the *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação – SBIE)* (Vol. 28, No. 1, p.714).

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2014). Du game design au gamefulness: définir la gamification. *Sciences du jeu*, (2).

IEEE. Standard for Learning Object Metadata. Disponível em: <http://ieeexplore.ieee.org/servlet/opac?punumber=8032> Acesso em: abr. 2018.

Lee, J. J., & Hammer, J. (2011). Gamification in education: What, how, why bother?. *Academic exchange quarterly*, *15*(2), 146.

Morin, Edgar; Alves, Nilda; Garcia, Regina (2002). Articular os saberes, O sentido da escola: 3.ed. Rio de Janeiro: Editora DP&A.

Nakazoni, I. A., Alexandrino, T. M., Garrido, U. J., Gasparini, I., & Henning, E. (2016). Análise, Desenvolvimento e Avaliação de um Objeto de Aprendizagem para Ensino Colaborativo de Frações, Números Decimais e Porcentagem. *RENOTE*, *14*(2).

Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context-aware computing for the internet of things: A survey. *IEEE communications surveys & tutorials*, *16*(1), 414-454.

Santos, B. P., Silva, L. A., Celes, C. S., Borges, J. B., Neto, B. S. P., Vieira, M. A. M., ... & Loureiro, A. A. (2016). Internet das coisas: da teoria à prática. *Minicursos SBRC-Simpósio Brasileiro de Redes de Computadores e Sistemas Distribuídos*.

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. *International Journal of human-computer studies*, *74*, 14-31.

Shenoy, Arjun. *IoT: Beyond the Buzz*. Disponível em: <https://dzone.com/articles/iot-beyond-the-buzz> Acesso em: abr. 2018.

Strapason, L. P. R. (2011). O uso de jogos como estratégia de ensino e aprendizagem da matemática no 1º ano do ensino médio.

Wiley, D. A. (2002). *The instructional use of learning objects* (Vol. 1). Bloomington, IN: Agency for instructional technology.