

Finite Set Algebra in Secondary School Using Raspberry Pi with Mathematica

Robert Ipanaqué-Chero(✉), Ricardo Velezmoro-León, Felícita M. Velásquez-Fernández, and Daniel A. Flores-Córdova

Departamento de Matemática, Universidad Nacional de Piura, Urb. Miraflores s/n Castilla, Piura, Peru
{ripanaquec,rvelezmorol,fvelasquezf,dflores}@unp.edu.pe

Abstract. The objective of this research is to automate the graphical representation of Finite Set Algebra, in order to provide: an alternative as a learning tool or a means to teach the association of mathematical concepts with the programming language, determine the construction rules and the Command programming in the subject of Basic Education Mathematics. This document describes a new Mathematica package, DiscreteSets.m programmed in PiWolfram. Since the Mathematica license is expensive, a Raspberry Pi computer is used since, thanks to its low cost and a free version of Mathematica that runs on it, it makes the new Mathematica package accessible to a greater number of users. To show the performance of the new package, a full set of illustrative examples is provided. This package admits as input a certain operation between two or three discrete and finite sets, whose elements can be numbers, letters or certain figures. And it returns as output the Venn diagram corresponding to the given operation, with the location of the elements of the sets similar to how they would be located manually. Allowing students to interactively learn and dabble in the PiWolfram programming language. Programming has been the cause of the great advances in technology. For this reason, it is important to incorporate technological education into the learning of Mathematics so that students appreciate the real importance of mathematics today.

Through mathematics we can understand the world around us. It is present in various human activities: daily life, social and cultural aspects, in such a way that it is an essential key to understanding and transforming culture. Having a mathematical development allows us to participate in the world in any of the aforementioned aspects.

Keywords: Automate · Algebra · Finite set · Raspberry Pi

1 Introduction

Through mathematics we can understand the world around us. It is present in various human activities: daily life, social and cultural aspects, in such a way that it is an essential key to understand and transform culture. Having a

© Springer Nature Switzerland AG 2021
O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12951, pp. 366–379, 2021.
https://doi.org/10.1007/978-3-030-86970-0_26

mathematical development allows us to participate in the world in any of the aforementioned aspects [2].

For this, it is important that the student understands that the competencies in the area of mathematics are linked with others, integrating in such a way that it allows them to understand, analyze, the variables that intervene when solving problems.

Some of the competences allow the student to characterize equivalences, generalize regularities and changes of one magnitude with respect to another through rules that allow finding values, restrictions and making predictions about the behavior of a phenomenon [3].

One of the relevant topics for the achievement of the aforementioned competence is the Algebra of Sets. Why should school students study, Algebra as a whole? Because they are present in everyday life through certain verbs that relate elements of two groups that are part of social, economic and cultural life, also in scientific matters. It is important to understand the nature of finite set Algebra through the type of association that exists between physical or mental objects that belong to certain sets.

According to many previous studies, learning mathematics through programming is a great advantage today. Well, it gives students a greater capacity for logical reasoning through structured thinking. The Wolfram Mathematica programming language has been used as a tool to address the Algebra of finite sets, which can be worked through an algorithmic design. We will define a program as a set of commands executed in a computer language that allow a machine to perform a series of operations automatically [4]. Programming is one of the few mental skills that allows students to explore the dynamics of their own thoughts, increase their capacity for self-criticism by correcting their mistakes, and also establish their logical reasoning through systematization [5].

Currently, software design and programming languages are in high demand in work environments, however, they are not addressed in the national curriculum of Peru. In other countries such as Spain, the US, Canada, EUROPE, the Middle East, Africa, China, New Zealand and Australia, they introduced the programming language as a means of curricular learning that influences all subjects [6].

The programming language should be incorporated in the last years of basic education or in the courses of the first year of university studies of general training. For this, mathematical knowledge must be structured in a similar way to the structure of a program in such a way that it is related to the concepts of computer science. For this, mathematical knowledge must be structured in a similar way to the structure of a program in such a way that it is related to the concepts of computer science. For students to acquire this ability according to [7], they achieve this under the guidance of the teacher, receiving the appropriate guidance on how to proceed so that they acquire the skill and then the student begins the exercise process in the necessary amount and with the appropriate frequency, so that reproduction is easy and whether to debug.

It is highlighted that the subject of finite set algebra allows us to analyze, classify and order the knowledge acquired by developing the complex conceptual network in which we store our learning. Therefore, given the importance of the subject, we seek to introduce programming; where the teacher guides the students to contemplate the presence of the association, determines the construction rules and programming commands.

In the work for research purposes, the theoretical concepts of the Algebra of finite sets were elaborated and taking into consideration the statement of UNESCO (2015): "the performance of Latin American students is affected by socioeconomic factors". In addition, considering the introduction of ICTs in all social areas, it is necessary to acquire digital skills through the use of the computer, this situation exacerbates learning gaps. An alternative to reverse this situation is to introduce the use of the Raspberry Pi microcomputer to education due to its low cost. Therefore, a finite set Algebra programming package was designed in the PiWolfram language. The objectives of this research were: Design a programming package in the PiWolfram language for learning Finite Set Algebra. Strengthen the computational thinking of high school students so that they have the ability to create algorithms and use different levels of abstraction to solve problems.

The structure of this article is as follows: Sect. 2 asks the research question: Why should school students study Algebra as a whole? and the importance of ensemble algebra is highlighted. In the Sect. 3 introduces the concepts of set, Venn diagram, cardinal of a set and algebra of set. It also talks about the Raspberry Pi Minicomputer and its Raspbian operating system, which is designed to interact with the PiWolfram language. In this language a mathematics package has been designed to represent the algebra of finite sets. Then in Sect. 4 Various studies related to our research that have been applied in secondary education are presented. Finally, the Sect. 5 closes with the main conclusions of this article where it is highlighted that the learning of Finite Set Algebra by students, through PiWolfram programming packages, strengthens reasoning and programming skills using a low-cost minicomputer.

2 Fundamentals

Currently there are advances in the teaching of mathematics in basic education, in this advance the use of technology as a tool has played an important role, it is an indicator of educational quality the use of ICT in teaching processes, technology at students' reach, such as the computer, which has made it possible for the explanation of certain mathematical arguments not to be so monotonous and boring, but rather to be perceived as a game when interacting with programming codes [8].

In basic education, the problems of finite set algebra, are currently solved manually and the only help some software provides is that they allow you to choose the figure you want to represent a set, offering no solution to the graphical representation with diagrams of Venn for operations between finite sets [9].

Students will be taught the automation and graphical representation of finite set algebra in order to provide an alternative to the traditional teaching methods of this subject in Basic Education Mathematics that incorporate the use of technological tools such as, in our case, commands and programs generated with Mathematica.

The contribution of this work consists of the development of a new Mathematica package, DiscreteSets.m, which automates the solution of problems related to operations in the algebra of finite sets. This package admits as input a certain operation between two or three discrete and finite cardinal sets, whose elements can be numbers, letters or certain figures. And it returns as output the Venn diagram corresponding to the given operation, with the location of the elements of the sets similar to how they would be located manually. In such a way that the user is in the possibility of obtaining an automatic solution of this type of operations by entering the respective entries.

There are very positive educational experiences with Wolfram Mathematica. An example is the teachers who incorporated it as an educational program, in their teaching processes together with an appropriate methodology such as Tpack and the creation of dynamic activities [10].

To encode the DiscreteSets.m package a Raspberry Pi 4 Model B computer is used, because it is possible to buy these computers for a price from 35 dollars and also because there is a free version 12 of Mathematica that runs in Raspbian OS for Raspberry Pi. This facilitates access to the package by a greater number of users [11–13].

3 Definitions and Basic Concepts

3.1 Finite Set Algebra

For programming the Algebra of Finite Sets, we will use definitions and examples that appear in this subsection have been taken of [2].

Set. A set is a well defined collection of objects. Objects in the set are called elements. Like other mathematical concepts, sets have their own notation and terminology. In general, we name sets with italicized capital letters and, when possible, list specific elements between braces: {}. For example, $A = \{1, 2, 3\}$ means that set A contains the elements 1, 2 and 3. To describe specific objects in the set, we can use the symbol $\in$to replace the words "is an element of" and $\notin$ to replace the words "is not an element of". For instance, we can write $1 \in$A and $4 \notin$ A.

Representing Sets. To this point, we have already seen two represent sets: rosters and set-builder notation. A roster is simply a list of the elements in the set. For example: $A = \{1, 3, 5, 7\}$ $B = \{blue, white, red\}$ Another way to represent sets is to use set-builder notation: {x | x satisfies some condition} The vertical bar (|) replaces the words "such that". So, we read set-builder notation as "The set of all x such that x satisfies some condition".

Empty Set. The empty set, or null set, written {} or ∅, is the set that contains no elements.

Universal Set. The universal set, or universe, written 𝕌, is the set of all possible elements in a given discussion.

Venn Diagrams. Venn diagrams are a third way to represent sets that use the notion of universal sets. The standard convention is to represent the universe with a rectangle and sets within the universe as circles. Let's look at Fig. 1, set A (the circle) is in universe 𝕌 (the rectangle). As we will see, Venn diagrams are a powerful way to represent sets and the relationships among them.

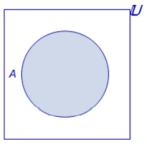


Fig. 1. Basic Venn diagram.

Subset and Proper Subset. Set A is a subset of set B, written A ⊆B, if and only if, every element of A is also an element of B. If B has an element that is not in A, then A is a proper subset of B, written A ⊂ B.

Cardinal Number. The cardinal number of a set A, written n(A), is the number of elements in A.

Finite Set. A set is finite if and only if:

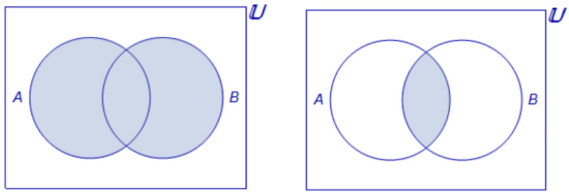
1. It is empty, or
2. There exists a 1–1 correspondence between the set and a set of the form {1,2,3,...,n}, where n is a natural number.

Union of Two Sets. The union of the two sets A and B, written A ⋓ B, is the set of all elements in A or in B or in both, let's look at Fig. 2(a). In set-builder notation,

$$A \cup B = \{x | x \in A \vee x \in B\}$$

Intersection of Two Sets. The intersection of two sets A and B, written A ∩ B, is the set of all elements common to A and B, let's look at Fig. 2(b). In set-builder notation,

$$A \cap B = \{x | x \in A \wedge x \in B\}$$



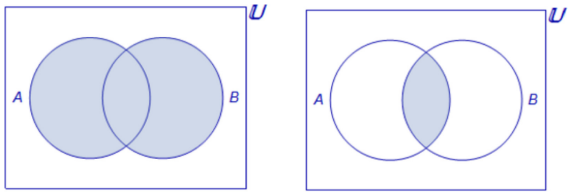
(a) (b)

Fig. 2. (a) Venn diagram of A ∪ B. (b) Venn diagram of A ∩ B.

Set Difference. The set difference of set B from set A, written A\B, is the set of all elements in A that are not in B (Fig. 3). In set-builder notation,

$A\backslash B = \{x|x \in A \wedge x \notin B\}$

Complement of a Set. The complement of a set A, written AC, is the set of all elements in the universe U that are not in A (Fig. 3). In set-builder notation, $A^c = \{x|x \in \mathbb{U} \wedge x \notin A\}$



(a) (b)

Fig. 3. (a) Venn diagram of A \ B. (b) Venn diagram of A^C.

Symmetric Difference of Two Sets. The symmetric difference is equivalent to the union of both relative complements (Fig. 4), that is:

$A/triangle B = (A\backslash B) \cup (B\backslash A)$

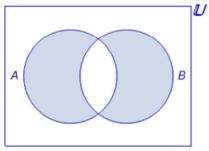


Fig. 4. Venn diagram of A△B.

3.2 Raspberry Pi with Mathematica the Raspberry Pi

La Raspberry Pi. The Raspberry Pi. It is a small, powerful and inexpensive single board computer developed over several years by the Raspberry Pi Foundation. If someone is looking for an inexpensive, small, easy-to-use computer for an upcoming project, or is interested in learning how computers work, then the Raspberry Pi is the right thing to do [1].

El Hardware Raspberry Pi. The Raspberry Pi's BCM2835 CPU runs at 700 MHz and its performance is roughly equivalent to that of a 300 MHz Pentium II computer that was available in 1999 [3].

The Raspberry Pi Foundation. It is a non-profit charity, founded in 2006 by Eben Upton, Rob Mullins, Jack Lang, and Alan Mycroft. The aim of this charity is to promote the study of computing among a generation that did not grow up with BBC Micro or Commodore 64 [1].

Raspberry Pi Models. It has several different variants. Model A is a low cost version and sadly omits the USB hub chip. This chip also works as a USB to Ethernet converter. The Raspberry Pi Foundation also just released the Raspberry Pi Model B + which has additional USB ports and solves many of the power issues surrounding the Model B and Model B USB ports [12], let's look at Fig. 5.



Fig. 5. Raspberry Pi 4 model B.

Operating System: Raspbian. Raspbian is the most popular Linux-based operating system based on Debian, which has been specifically modified for the Raspberry Pi (hence the name Raspbian). Raspbian includes customizations that are designed to make the Raspberry Pi easier to use and includes many different out-of-the-box software packages [12].

Wolfram Language. Makes cutting-edge computing accessible to everyone. Unique in its approach to building vast knowledge and automation, the Wolfram Language scales from a single line of easy-to-understand interactive code to production systems of one million lines [8].

Mathematica. Es un producto original y más conocido de Wolfram, destinado principalmente a la informática técnica para la investigación, el desarrollo y la educación. Basado en Wolfram Language, Mathematica es 100% compatible con otros productos [8].

Raspberry Pi Con Mathematica. Una versión completa de Wolfram Language está disponible para la computadora Raspberry Pi y viene incluida con el sistema operativo Rasp bian. Los programas se pueden ejecutar desde una línea de comandos de Pi o como proceso kground, asícomo a través de una interfaz de computadora portátil en Pi o en una computadora remota. En Pi, Wolfram Language admite acceso programático directo a puertos y dispositivos Pi estándar [8] (Fig. 6).

3.3 Free Wolfram Language and Mathematica on Every Raspberry Pi

The Wolfram Language and Mathematica are included in the Raspberry Pi NOOBS (New Out of Box Software) installation system.



Fig. 6. Mathematica and every Raspberry Pi.

In the Raspberry Pi 4 version, Mathematica Version 12 and the Wolfram Language are available. With a wide range of features, including a significant expansion of numerical, mathematical and geometric computing, audio and signal processing, text and language processing, machine learning, neural networks and others. Version 12 brings Mathematica users new levels of power and effectiveness, with updates to its functions and areas. Mathematica 12 runs significantly faster on the Raspberry Pi 4 than it did in previous versions. Where you can carry out projects from the creation of weather panels to the creation of tools that use machine learning and the execution of command line scripts [17].

3.4 A Mathematica Package for the Graphic Representation of the Finite Set Algebra

This section describes the new Mathematica package, DiscreteSets.m, we developed for the graphic representation of the finite set algebra. We will begin by indicating that Mathematica does not incorporate any native function to obtain the Venn diagram of the operations between two or three given sets, and even less to obtain a Venn diagram in which the elements of the assemblies are placed, according to the operations that are indicated. To encode the new package we use

Mathematica's ability to manipulate and convert strings of characters. Thanks to this it is possible to enter the operations between sets affected by quotes, which is the standard way to enter strings in Mathematica. Mathematica's ability to manipulate lists allowed us to enter the elements of all the sets that participate in the operations. Mathematica's ability to represent circumferences and regions of the plane is also used. This capacity allows to represent the sets by means of circles and to shade those parts that correspond to the solution of the given operations. Finally, the algorithms with which the polygons that make up the different regions into which the plane is divided (according to the number of sets involved in the given operation) are used to take some vertices, of such polygons, on whose coordinates are locate the elements of the sets.

Ahora, comenzamos nuestra discusión del nuevo paquete accediendo a Mathematica en Raspberry Pi, let's look at Fig. 7.

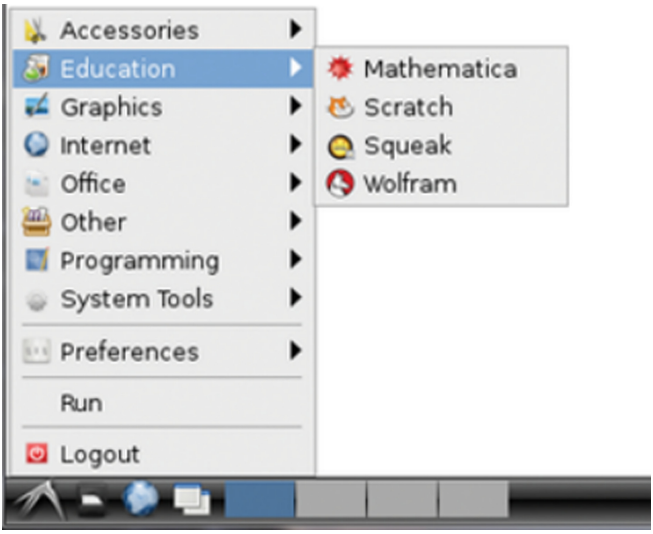


Fig. 7. Accessing mathematica in Raspberry Pi.

Then, we loading the package:
<<DiscreteSets.m

The main function, VennDiagram, supports a maximum of five arguments and at least two, namely:

- an operation between sets as a character string.
- the sets /(one to three sets7) and, optionally, the universe according to the syntax.

$VennDiagram[\text{“}operation\text{”}, A \to \{a1, ..., an\}, ..., Universe \to \{u1, ..., um\}]$
Below are some examples that show the functionality of the VennDiagram function. The first example is arguably one that students should know how to deal with:

VennDiagram[“A”, A → {1, 2, 3, 4, 5, 7}. Let’s look at Fig. 8.

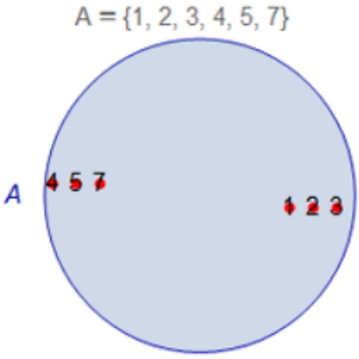
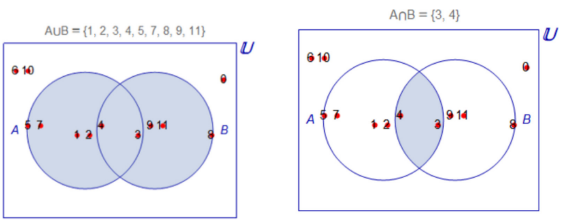


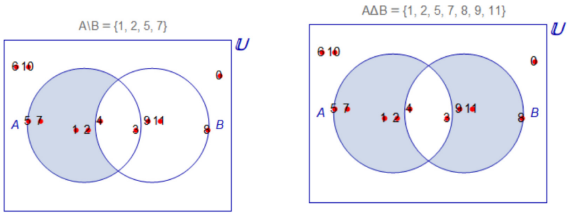
Fig. 8. Venn diagram of set A.

The same comment applies here (the reader is kindly invited to try manually these four examples by him/herself):
$VennDiagram[\text{“}A \cup B'', A \to \{1,2,3,4,5,7\}, B \to \{3,4,8,9,11\}, Universe \to \{0,1,2,3,4,5,6,7,8,9,10,11\}]$. Let’s look at Fig. 9(a).
$VennDiagram[\text{“}A \cap B'', A \to \{1,2,3,4,5,7\}, B \to \{3,4,8,9,11\}, Universe \to \{0,1,2,3,4,5,6,7,8,9,10,11\}]$. Let’s look at Fig. 9(b).
$VennDiagram[\text{“}A \setminus B'', A \to \{1,2,3,4,5,7\}, B \to \{3,4,8,9,11\}, Universe \to \{0,1,2,3,4,5,6,7,8,9,10,11\}]$. Let’s look at Fig. 10(a).
$VennDiagram[\text{“}A \triangle B'', A \to \{1,2,3,4,5,7\}, B \to \{3,4,8,9,11\}, Universe \to \{0,1,2,3,4,5,6,7,8,9,10,11\}]$. Let’s look at Fig. 10(b).



(a) (b)

Fig. 9. (a) Venn diagram of A ∪ B. (b) Venn diagram of A ∩ B.



(a) (b)

Fig. 10. (c) Venn diagram of A\B. (d) Venn diagram of A △ B.

On the contrary, this example (which involves three sets) is not that easy: $VennDiagram[\text{“}((A \cup B) \cap C) \setminus (A \cap B)'', A \rightarrow \{1,2,3,4,5,7\}, B \rightarrow \{3,4,8,9,11\}, C \rightarrow \{2,3,4,6,10,11\}, Universe \rightarrow \{0,1,2,3,4,5,6,7,8,9,10,11,12\}]$. Let's look at Fig. 11.

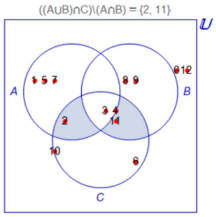
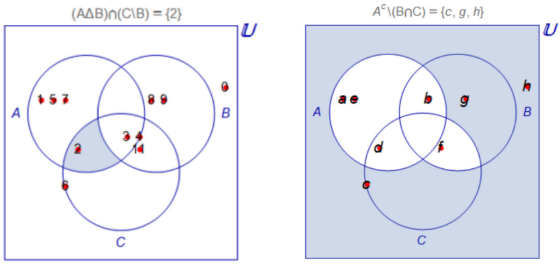


Fig. 11. Venn diagram of ((A ∪ B) ∩ C) \ (A ∩ B).

This other example is not quite simple either: $VennDiagram[\text{“}(A \triangle B) \cap (C \setminus B)'', A \rightarrow \{1,2,3,4,5,7\}, B \rightarrow \{3,4,8,9,11\}, C \rightarrow \{2,3,4,6,10,11\}, Universe \rightarrow \{0,1,2,3,4,5,6,7,8,9,10,11\}]$. Let's look at Fig. 12(a).



(a) (b)

Fig. 12. (a). Venn diagram of (A △ B) ∩ (C \ B). (b) Venn diagram of Ac \ (B ∩ C).

In the following example sets' elements are letters of the alphabet: $VennDiagram[\text{“}A^C \setminus (B \cap C)'', A \rightarrow \{a, b, d, e\}, B \rightarrow \{b, f, g\}, C \rightarrow \{c, d, f\}, Universe \rightarrow \{a, b, c, d, e, f, g, h\}]$. Let's look at Fig. 12(b).

In this last example sets' elements are symbols: $VennDiagram[\text{“}(A \cup B) \cap (C \triangle B)^C\text{”}, A \rightarrow \{\diamond, \bigtriangledown, \square, \blacksquare\}, B \rightarrow \{\blacklozenge, \heartsuit, \square\}, C \rightarrow \{\bigstar, \heartsuit, \nabla, \blacklozenge\}, Universe \rightarrow \{\triangledown, \square, \diamondsuit, \blacklozenge, \blacksquare, \blacktriangledown, \bigstar, \heartsuit, \spadesuit\}]$. Let's look at Fig. 13.

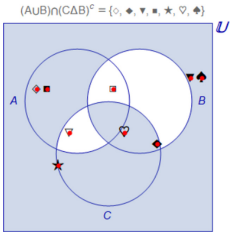


Fig. 13. Venn diagram of $A^C \setminus$ (B ∩ C)

4 Related Research

Much has been said and written about the potential applications of computer algebra systems to mathematics education. In fact, this is a hot topic of many conferences and workshops related to educational topics, where they make arguments in favor of the inclusion of computer algebra systems in the mathematics curriculum from the middle school level to the upper level as a middle school. aid in problem solving Its use in education should always be subject to feedback according to the teacher's experiences and research in education [14].

By contrast, less has been said on the specific subject of teaching and learning the graphic representation of finite set algebra [15]. Among those rare papers on this issue, the authors found a very nice work a question and answer site for users of Wolfram Mathematica in which a user showed how Mathematica can be adequately used to create a Venn Diagram for three sets [16]. However, the focus in such a document was basically the location of the elements in the diagram, according to the set to which they belonged, without taking into account any type of operation. Because of this limited goal, [16] did not introduce any new command; standard Mathematica commands seem to be good enough to make pictures, as opposed to our approach, for which new symbolic commands are actually required. In this sense, this paper goes far beyond [16]. We have introduced a computer tool that can be used for Mathematics of Basic Education. Even teachers and instructors can benefit from this tool. For instance, we can propose to our students to verify if the result of an operation between two or three sets is mathematically correct.

Among the various jobs related to research, we highlight the work done by Handley, N. and Meacham, S. [18]. They were raised by objective to create

solutions to help elementary students learn, in mastery of counting using visual representations. Using a Raspberry Pi they developed prototypes of low-cost interactive solutions that can help learning in this area.

The research by Musyrifah, E., Rabbani, H., Sobiruddin, D. and Khairunnisa K. [19] that sought to incorporate Mathematica software into the learning of Mathematics as an interactive tool. They emphasize that the available texts seem monotonous and do not allow students to understand derivative concepts. They developed didactic materials in learning modules with the Wolfram Mathematica application using the ADDIE development model, being evaluated by teachers and students, who considered it adequate.

The study by Kaufmann, O. and Stenseth, B [20], a group of high school students who applied programming using Processing to solve mathematical problems was observed. An important finding they obtained is that the students progressed in the argumentation categories from the simplest to the most elaborate.

In each of the aforementioned works, the aim is to improve the quality of mathematics learning using specialized mathematics software with an interactive tool that strengthens cognitive abilities, to achieve the students' competencies. Developing in them skills, abilities and attitudes to understand the world around them and be able to create algorithms that help automate solutions.

5 Conclusions

This article introduces a new Mathematica package that enables you to place the elements that satisfy operations between two or three sets automatically in the graphical representation of such operations in a Venn diagram. The package includes commands for graphical output that allow users to grasp the ideas behind this concept. Additionally, a Raspberry Pi computer is used since, thanks to its low cost and a free version of Mathematica that runs on it, it makes the Mathematica package accessible to a greater number of users. It should be noted that there is a slight variation between the code executed on a traditional laptop and that executed on a Raspberry Pi, this occurs specifically in the construction of graphics using primitives. To show the performance of the main commands, a full set of illustrative examples is provided. Teachers will be able to use the Mathematica package to make their classes very interactive using the appropriate strategies or to teach programming using the Mathematica programming language after training in the Software.

References

1. Harrington, W.: Learning Raspbian. Packt Publishing Ltd. (2015)
2. MINEDU, Qué y cómo aprenden nuestro niños. http://www.minedu.gob.pe/DeInteres/pdf/documentos-secundaria-matematica-vii.pdf. Accessed 24 Feb 2021
3. MINEDU. http://www.minedu.gob.pe/curriculo/pdf/03062016-programa-nivel-secundaria-ebr.pdf. Accessed 24 Feb 2021
4. Wilkes, M.: Automatic digital computers Location, 1st edn. Methuen & Co., Ltd (1956)

5. Briz, A., Serrano, A.: Aprendizaje de las matemáticas a través del lenguaje de programación R en Educación Secundaria. SciELO, vol. 30(1) (2018)
6. Yábar, J.M.: Informática y matemáticas. 'Quién apoya a quién?. Uno-Revista de Didáctica de las Matemáticas. (Núm)006
7. López, M.: 'Sabes enseñar a describir, definir, argumentar.- Revista de Didáctica de las Matemáticas La Habana: Pueblo y Educación. 1990
8. Pelgrum, W.J., Law, N.: ICT in Education Around the World: Trends, Problems and Prospects, vol. 77. Unesco, International Institute for Educational Planning (2003)
9. Collins, S.O.: Raspberry Pi 4 User Guide: The New Updated Guide to Master the New Raspberry Pi 4 and Make, Build. Independently Published, Or Hack a Variety of Amazing Projects (2019)
10. Castañeda, F.: Actividades de aprendizaje para la enseñanza de la Matemática utilizando Geogebra y Wolfram Mathematica para estudiantes de décimo año de educación general básica de la Unidad Educativa Capitán Edmundo Chiriboga. Universidad Nacional de Chimborazo (2020). http://dspace.unach.edu.ec/handle/51000/6516. Accessed 24 Feb 2021
11. Raspbian OS Programming with the Raspberry Pi. Apress, Berkeley, CA (2019). https://doi.org/10.1007/978-1-4842-4212-4
12. Wolfram: Wolfram Language y Mathematica gratis en cada Raspberry Pi. https://www.wolfram.com/raspberry-pi/index.php.es?source=footer. Accessed 24 Feb 2021
13. Xataka: Raspberry Pi 4 es oficial: una completa actualización con procesador Cortex-A72, hasta 4 GB de RAM y desde 35 dólares. https://www.xataka.com/ordenadores/raspberry-pi-4-caracteristicas-precio-fichatecnica. Accessed 4 Feb 2020
14. Salat, R.: El potencial de los sistemas de álgebra computacional.Revista de Didáctica de las Matemáticas, vol (81) (2012)
15. Zevallos, A: Como hacer Diagramas de Ven Online- Representación Gráfica de Conjuntos en línea. https://wolframalpha0.blogspot.com/2014/01/como-hacer-diagramas-de-venn-online.html. Accessed 4 Feb 2020
16. StackExchange: Create a Venn Diagram. https://mathematica.stackexchange.com/questions/134014/create-a-venn-diagram. Accessed 4 Feb 2020
17. Wolfram: Mathematica 12 disponible en la nueva Raspberry Pi 4. https://blog.wolfram.com/2019/07/11/mathematica-12-available-on-the-new-raspberry-pi-4/. Accessed 4 Feb 2020
18. Handley, N., Meacham, S.: Raspberry Pi based solution for Primary Schools Mathematics Education. In: Conference: BCS SQM/Inspire Conference 2016
19. Musyrifah, E. et al.: Development of wolfram mathematica application-assisted learning module on derivative in high school. J. Phys. Conf. Ser. **1836**(1). https://doi.org/10.1088/1742-6596/1836/1/012076
20. Kaufmann, O., Stenseth, B.: Programning in mathematics education. Int. J. Math. Educ. Sci. Technol. (52) (2021). https://doi.org/10.1080/0020739X.2020.1736349