RasberryPi-based solution for primary schools mathematics education

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Abstract

This paper discusses the use of modern "credit card sized computers" such as the Raspberry Pi to create solutions designed to aid the learning and mastery of beginner mathematics in young children, specifically number bonds. The way in which children are taught and the tools available to them grow and evolve. Our Raspberry Pi solutions are specifically aimed at assisting learning during the pictorial stage in which children move from counting with physical items such as blocks to visual representations. Using a Raspberry Pi allows for easier development of prototype solutions that can be interactive, educational and exciting to use, as well as other benefits such as costs and ease of development and building. By creating multiple solutions and gaining feedback with the help of a local school, I plan to create an artifact that is proven to help in this area of learning.

Keywords: RaspberryPi, STEM, education, microprocessor-based systems

1.0 Introduction

This paper focuses on our work towards my final year dissertation project up to its current point of implementation to date. It will summarise some of the key points of the development process including working with the client, gaining requirements, additional research, designs and implementation. Due to the nature of this project and its current status this should by no means reflect the end product, research or conclusions made by the project. In the mentioned project, the Raspberry Pi is one of the fundamental components along with the motivation to utilise it to create a system that is designed to aid the education of young children.

The project has worked in collaboration among ourselves and Halterworth Primary School, Romsey. Having support from the school allowed us to design and begin implementation on possible solutions that would help towards a specific area of their learning using our designed systems. The collaboration with Halterworth Primary allowed for a far better understanding of current educational trends, teaching methods and problems that occur. This was a vital part of the project which had so far lead to a number of specific decisions during its design phase [1].

2.0 Meeting

Once collaboration from Halterworth was confirmed for the project, an initial meeting took place. During this meeting there were discussion regarding what areas of early learning could benefit from a new Raspberry Pi based solution. Mathematics and English were possible candidates however it was agreed that Mathematics could be the best approach as they appear to be an area for improvement during the "pictorial representational" stage of their learning of number-bonds; all combination of numbers which make up a larger number. Pictorial representation comes after concrete representation in which children use physical items such as blocks to grasp the initial concept of maths [2]. The solutions designed to date are aimed specifically to help during this stage in which children try and use only visual representations to solve problems. The current trend in early education that was explained is "mastery of learning". "The essential idea behind mastery is that all children need a deep understanding of the mathematics they are learning" [3]. This means that children are now taught to know how to use numbers instead to remember, such as our times tables. This is something we aim to accomplish within our solutions.

It was documented that a fundamental requirement for this project to succeed with the children was simplicity. Current solutions included small abacus-like apparatus which were only possible for one number at a time and not very attention capturing, as well as online games which although visually stimulating, were limited in what they could offer. It was apparent that both were very simple which increased their usefulness. The online games attractiveness came down to their interactivity; being able to click buttons and sounds being produced. There were aspects of the current solutions that could be used and adapted for our Raspberry Pi alternative. The most important conclusion was that simplicity is not to be underestimated. Complex solutions can bore and confuse children. For example, if a solution is to be interactive, we should not have too much going on at once.

Another was that limited functionality causes limited use of the solutions. If a solution was able to incorporate a different range of alternatives it can extend its usefulness. An example given is the idea of using a solution on your own or together with another, multiple number bonds possible such as 3-to-10 and not just 3 *or* 10.

A final summarising point which was not expected and came out in the discussion with the school was the idea of "multiplayer" or having children play *against* each other. Some of the examples given are from the BBC [4] which have this capability which encouraged children to use the tools further if there was an aspect of competition which we did not expect to see in learning at a young age. The project plans to look further into the effects of competitiveness in learning to determine its pros and cons and evaluate its place in the project. With this information available further research into gamification to the solutions by adding different levels/difficulties, points for correct answers, winners and losers in games and more.

3.0 Research

3.1 IT in Mathematics

One key area of research was if IT can work well in aiding learning of mathematics in primary schools, if there are any problems with this approach and how these could be overcome to ensure greater success with our project.

IT has been incorporated into learning for some time and has seen a number of benefits for teachers and pupils. Some of the benefits for IT while teaching maths are the collaboration between students, increased focus on techniques, fast feedback to student and increased motivation [5]. It has also been shown that "children intuitively know how to use computers" and are happy to use them even with a teachers apparent lack of confidence [6]. If children intuitively know how to use modern day devices, in some cases more than the adults trying to teach them, perhaps this should be embraced by providing intuitive solutions to help their learning. Further research showed problems that need to be considered when using an IT approach to mathematics. As that was found in the literature, children often have a "lack of fear, especially in contrast to the practitioners' lack of confidence" [6] and that "integration of ICT into subject teaching depends upon teacher confidence and skill and varies widely within a school" [7] demonstrated that the benefit that certain solutions can provide could be limited by "lack of time in the school schedule for projects involving ICT", "insufficient teacher training opportunities" and "lack of knowledge about ways to integrate ICT" [8] to name a few. This highlighted that any solution the project provides should not only be simple and intuitive to use for children, but also for teachers who will be facilitating their learning with these technologies. A case is explained regarding a Raspberry Pi system that could aid in this problem. These devices which can be run 'headless' to increase its portability, can affect its usability. A number of possible solutions are touched upon such as having the solution run on start-up, having any GPIO pins in use easy to plug-and-play or no command line input; anything that can increase the usability of the solution from teachers perspective.

3.2 Gamification

Another large area of research in this project was gamification. Gamification is the technique of "using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning, and solve problems" [9]. Including gamification in this project could take it one step further from being a solution that children are happy to use when asked, to something they actually ask to use. We refer to Huang and Soman [10] specify a 5 step process.

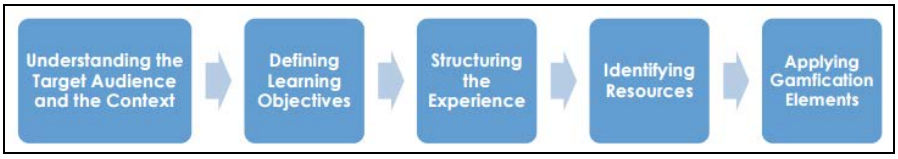

Figure 1: Huang & Soman 5 Step Process

These steps go all the way through the process of successfully implementing gamification to an educational program. It starts with understanding the students such as their age range, what they understand so far, even when the activity may take place. Next would be defining learning objectives and specific goals. In our project, we are aiming at year 1 children and number bonds. An objective could be to be able to achieve a certain score by a specific date or to enhance their understanding of a specific set of number bonds they struggle with. The third stage discusses breaking down the experience and realising where the "pain points" could be. These are potential problems that may occur such as loss of focus or motivation, the skill needed being too high or low, pride from learning something you feel you should know, physical and metal factors and lastly the environmental factors. The pain points can potentially be remedied with the use of complete or push stages to reward students by completing their current stage and moving onto the next. This could be in the form of completing lower level number bonds such as 1-3 and then moving onto 4-6 and so on. The penultimate stage is deciding what resources would benefit the educational software. These can range from progress tracking, 'currency' which can come in the form of points or trophies but usually anything collectable, are there rules that need to be added to the experience, and is there any feedback from the system. The final stage takes all of this data and applies them for the best formula. Using this process, the project will take a step from a simple maths program, to something much more gamified when included in current designs.

4.0 Other Projects

An area of this project which is not complete and requires further investigation is what projects already exist out there which have similar goals to this project when completed. Initial research had found no other examples that share a core objective to use a Raspberry Pi to teach maths to infant school children. There was however information on two tools which come as part of the Raspberry Pi default operating system, Raspbian, Mathematica and Scratch.

4.1 Mathematica

Mathematica is "primarily aimed at technical computing for R&D and education" [11] and built using the Wolfram language. The area of education that Mathematica aims for is far beyond that of the infant school level that this project was trying to achieve. It is typically used at the A-level and above in advanced mathematics. Although the product seems to work very well at this level [12] it is not suited well for the fundamentals on maths.

4.2 Scratch

Scratch is primarily used to teach coding skills by creating stories and games. These games are very simple and some have been designed with education in mind. “Scratch is designed especially for ages 8 to 16, but is used by people of all ages” [13]. As mentioned, Scratch comes with the Raspbian Operating system. This tools has recently updated to allow for GPIO support which allows for GPIO pins to be used as part of Scratch projects. Although this functionality is possible, we have not yet found an example which utilises this, but instead found many examples such as the “Maths Race” [14] seen in figure two, where two animals race based on the correct or incorrect answers provided.

Figure 2: Maths Race Screenshot [12]

The negatives to the use of scratch however is it would require a display and could not be used headless. The effect of this could be added complication but could also make gamification far more viable.

5.0 Designs

At this stage of the project, designs have not been finalised and are still being developed. Multiple different designs had been created to utilise a number of different pieces of equipment to see how they work. From the project we will discuss two designs, one single and one multiplayer designs. The first will be the single player, multiple choice, LCD design seen to the left of figure three. This first design displays a maths question such as “3 + ? = 10” on the first line and 3 possible answers below which correspond to the button below the answer. This is repeated 10 times and a score out of 10 can be provided. The second of the 2 designs encourages multiplayer by having one button for each person, and a corresponding LED for that player to denote a team colour which will flash on a correct answer. Currently a maths question, same as before is displayed via the terminal. The 7 segment display then cycles through possible digits from 0 – 10. If either button is pressed while the correct number is on display, they are awarded a point. This currently takes the same format as the previous game which is best out of 10. We have mentioned that one of the draw back to current tools is their diversity, for example being limited to one number. With many of the designs, including these show, they are expandable and diverse. The hardware does not need to change to allow for either solution to have the sum number as any other number. The scoring system is also interchangeable from out of 10, to first to 10 as well as scoring based upon fastest correct answers and penalising for incorrect answer to deter guessing. We have used an example which the sum number is always the same (for the set number of questions) to aid with the learning of number bonds for that number, however the answer can be changed in the software to alter the equation to something such as “4 + 3 = ?” to allow for a different type of mathematics, possibly at a different age, once again adding to the usefulness of these designs. Documentation of designs so far have attempted to utilise simplicity by using the minimum number of components however we feel the interpretation of simplicity could be down to the user so is only speculation at the current time.

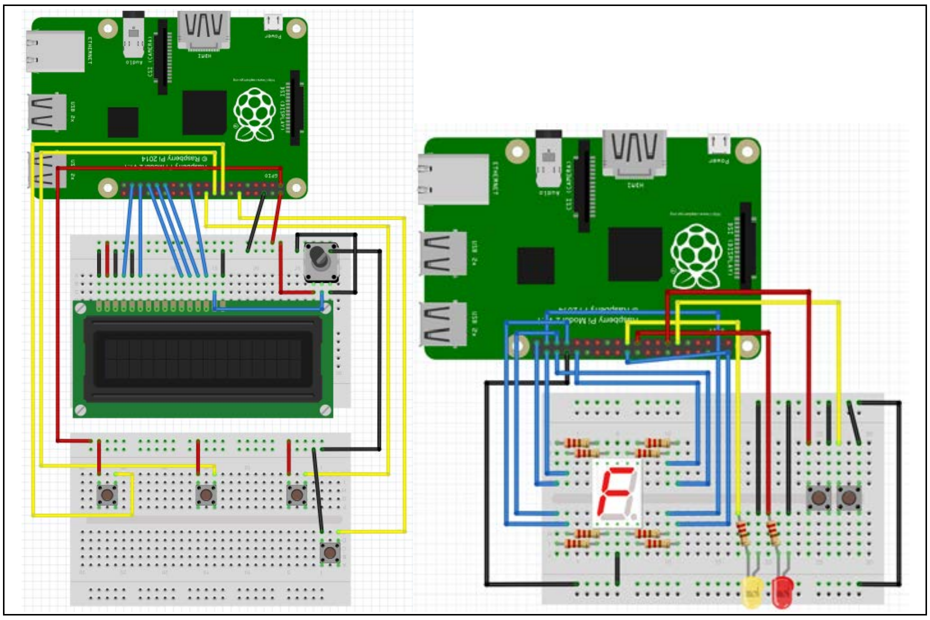

Figure 3 - Left, single player LCD game. Right, 2 player game. [1]

It should be noted that these early designs were created with the idea of no desktop display being used therefore eliminating the possibility of integrating with a Scratch game. Designs will be worked on in future sprints to incorporate such functionality to determine if they are a benefit to the project or necessary at all.

5.0 Closing Remarks

This summary should have covered the basics of our requirements, research, designs and where our implementation will eventually lead us. We are confident that our project can fulfil its goal in successfully creating a tool which is simple and effective of aiding the learning of number bonds and mathematics in young children. Data on of our project will be collected later this year which with a meeting at Halterworth school which will allow us to quantify the pros and cons of certain designs. We hope the conclusion of this project provides a useable solution and also encourages more IT solutions in mathematics aimed at younger children which resolve some of the problems highlighted.

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