

An Exploration In The Use Of Minecraft To Teach Digital Logic To Secondary School Students

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Abstract

Logical thinking and analytical skills are a key component of any STEM discipline. It is understood that secondary students lack this ability. We present experimental results from using Minecraft to teach these skills for secondary students.

Index Terms - Analytical and logical thinking, Minecraft, digital logic.

I. INTRODUCTION

Many students are turned away by words like 'mathematics', 'engineering', and 'science' due to the highly technical nature of these subjects. Authors have noted that when faced with a problem that doesn't have a specific formula, learners often don't know how to solve them, even if they already have all the knowledge behind the concepts (Bako, nd).

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Research suggests that some of these difficulties can be alleviated by introducing students to logical thinking and applications of extending logic to situations that have relevance to real world situations. Tarasenkova and Akulenko (2014) argue that applied concepts should be taught alongside abstract ones in mathematics, and offer several outlines for integrating logic into instruction. Finding a right medium to provide instruction that introduces logical thinking that is relatable to students is one of the keys to obtain successful results. We propose that the popular computer game Minecraft can be used in this fashion.

II. LITERATURE REVIEW

Digital logic is the mathematical expression of the principles of logic in terms of binary digits. This allows the translation of complex logical arguments into simple true/false questions and also the design of complex circuits which involve such decision making. Students learn the basics of how machines make decisions based on the answers to these yes/no questions. Truth tables, Venn diagrams and other such tools are used to teach how the process of logic works and interpreted by machines. Additionally, these skills also help students develop skills such as being able to think sequentially, refute erroneous conclusions and construct valid arguments all of which lay the foundation for computational skills which are required for any STEM discipline (Abdullah et al. (2008), Ekaputra, Lim, Eng (2013), Ren, Guo, Wo (2008)).

Additionally research has documented that high school students exposed to topics including deductive and propositional logic, as well as Boolean algebra, have shown better analytical and critical thinking skills in both academics and day to day tasks, like using search engines and picking out the relevant results (Bouhnik, D and Giat, Y (2009)).

Researchers in this project used Minecraft, a popular online game to introduce digital logic to high school students. Researchers have used Minecraft in educational settings, including using it to engage students in teaching and learning English and to build and mimic various components of a computer (Schifter & Cipollone, 2013). The next sections of the paper provide details on the experimental setup and initial student results from this research activity.

III. AUDIENCE AND EXPERIMENT SETUP

The audience in this research activity were middle and high school students who were already familiar with Minecraft. Our purpose was to use this tool as a vehicle of instruction to teach digital logic. Students were immediately more engaged when applying new concepts to an already familiar virtual environment, and the Redstone Blocks available in every version of Minecraft can be used to explain many basic logic concepts. These concepts can be applied to more complex topics in science and mathematics and make them both easier to understand and more enjoyable for students to learn about.

IV. PEDAGOGICAL FOUNDATION

The pedagogy used was grounded in Bloom's taxonomy and includes a gradual progression and scaffolding where students use the previously learned material to learn the concepts of the next level. Table 1 describes the relationship between activities in Minecraft and Bloom's Taxonomy of Cognitive Domains.

Minecraft Activity	Bloom's Taxonomy (Revised)
Initial discussion on the required theoretical concepts.	Remembering, Understanding
Paper Pencil activity	Applying, Analyzing
Evaluate the results from the paper pencil activity, and use the results to create in game scenes in Minecraft	Evaluating, Creating

Table 1 – Mapping of Minecraft activity to Bloom’s Taxonomy

The topics discussed in this experiment include digital logic and the Binary system with subtopics such as logic gates, truth tables, K-Maps and their applications within an in game context of Minecraft.

II. INSTRUCTION OF LOGICAL GATES

Students learned that all information sent to a computer must ultimately reduce to 0s and 1s which translate to specific instructions for the processor. Students were introduced to digital logic using simple to more complex truth tables and binary system. (Note: no binary elimination is done at this step) Students explored the basic logic gates: AND, OR, NOT, NOR, NAND, XOR, and XNOR. Each of these gates were explained in terms of inputs and outputs. This was followed by a mathematical representation such as $A*B$ for AND, followed by a the circuit symbol. Truth tables were used to record input and output values.

These foundations were then expanded using practical applications. An example activity was described about the making of soup. Students were presented with a list of available ingredients: A the broth, B a vegetable, and C a fruit. The rules for the function were that broth is a necessary ingredient, and the soup can have either a vegetable or a fruit but not both. *This activity maps to the remembering and understanding level of Bloom’s taxonomy, and is detailed by the following truth table.*

C/AB	00	01	10	11
0	$A'B'C'$	$A'BC'$	$AB'C'$	ABC'
1	$A'B'C$	$A'BC$	$AB'C$	ABC

A	B	C	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	0

Table 2: The Truth Table created for the soup function

The resulting truth table in table 2 is simple and straightforward, there are only two true values in the function column. This makes it easy for the students to see exactly why only those two values are true and also makes it more difficult for them to randomly guess because of the large number of 0's.

Students were then guided to the next level of abstraction. The resulting K-Map is also useful because it does not require grouping. The students are then introduced to Karnaugh Maps as a way to take the Function values and make them into something more useful. The resulting K-Map of the soup function can be seen in table 3.

C/AB	00	01	10	11
0	0	0	0	1
1	0	0	1	0

Table 3: The K-Map for the soup function

Students then simplified the K-Map by creating groups and seeing where those group are in accordance to the values on the top of the map. Table 4 contains all the mapped values for a K-Map with three inputs A, B, and C. Using the equation found from the K-Map it is then proved that the equation is in fact the output function. The output equation for the example soup function is the or of where the two ones are found or $ABC' + AB'C$. Table 5 contains the table that proves that F is in fact $ABC' + AB'C$. *This part of the activity maps to application and analysis levels of Bloom's taxonomy.*

Table 4: The mathematical representation of each entry in the K-Map

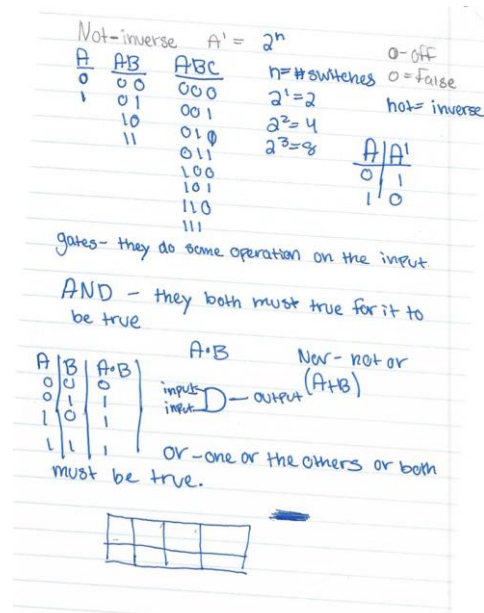


Figure 2: Student Work For Initial Analysis

The final level of abstraction focused on creating a circuit diagram from the equation that was found with the K-Map. The circuit schematic can be seen in Figure 1. In Minecraft it is difficult to make AND gates that have more than two inputs. In order to keep things as consistent as possible and to make the circuit representation of the equation, Students analyze the given inputs, track the returned output and evaluate the accuracy of a given function in terms of the inputs given to the function and outputs returned by the function. *This activity further ensures that students practice skills related to analysis and evaluation aspects of Bloom's taxonomy.*

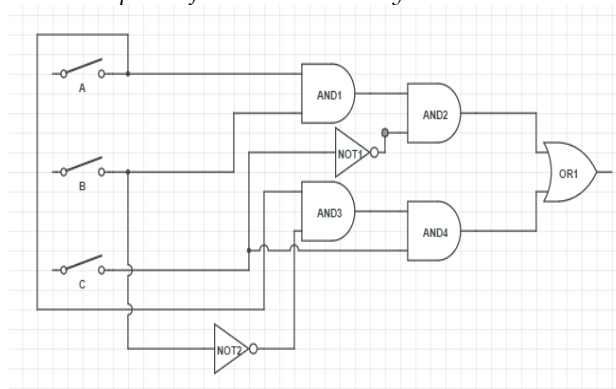


Figure 1: The circuit diagram for the example soup equation

Finally, students build a circuit in Minecraft. The gates are not available as items that can be dragged and dropped in Minecraft and must be created by the students. The diagram below shows redstone gates that the students used in their projects.

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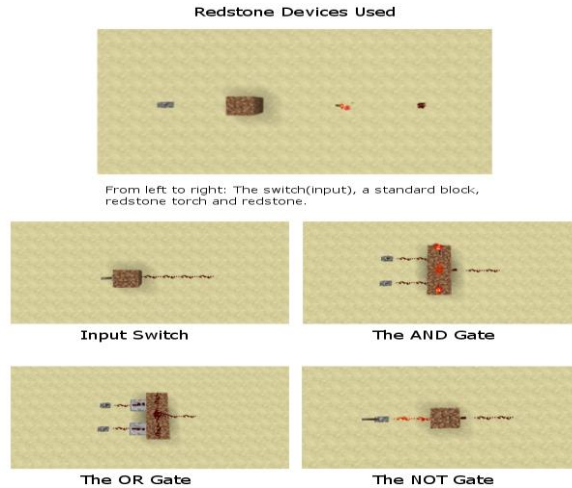
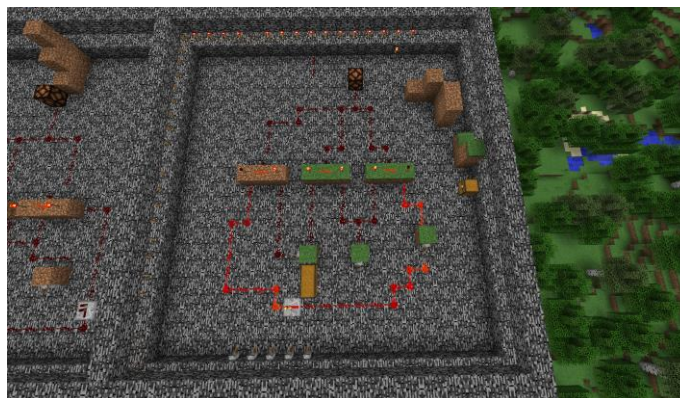


Figure 2: The common Minecraft redstone gates from minecraftwiki.gamepedia.com

Following the schematics in Figure 2, basic logic gates can be created in Minecraft. The switches are used as the three inputs A, B and C and are wired to their respective gates. The output is wired to a light that is "on" when the redstone signal is on and "off" when the redstone signal is off. This mechanism allows students to create digital logic systems and get feedback instantly. At any time the student can flip the switches and observe the feedback of the system. Students learn about circuits and digital logic in a safe and engaging learning environment. It is a safe environment for middle school students since they cannot burn up any parts, faulty parts, and no electricity being exposed to the students.

Sample Student Work from this activity

After going through the steps listed above, students were asked to create their own game in Minecraft including at least one or two logic gates. Students could do this very easily after the activity listed above and were very creative in their projects. Presented below are some screenshots of their activities.





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