

Using a Sudoku Lab to Motivate Students in an Introductory Course

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Abstract: This paper describes a computer laboratory activity on Sudoku puzzles the authors developed while at West Virginia University. This activity was used in a beginning Liberal Arts Math course in an effort to motivate students. The lab, solutions, and samples of student work are given. Furthermore, results from an anonymous survey given to the students about their attitudes toward the lab and class are included. The survey results are generally positive and the lab seems to have increased student interest in Sudoku puzzles.

Beginning courses present many unique teaching challenges. As an instructor, it often seems that many students in such courses have a negative view of mathematics, particularly in basic or liberal arts mathematics courses. These courses can be filled with apathy, stress, and poor motivation. Many students in these courses do not see the importance or utility of mathematics. As a teacher, how does one deal with this issue?

One method of motivating students is using activities that are of special interest to the students. The purpose of this article is to describe a computer laboratory activity on Sudoku puzzles that has been used in a Liberal Arts Math (LAM) course in an effort to engage students in mathematics. This particular course is offered at the university level, but the activity could be used in many different classes at many different levels.

Our LAM course is designed to give students an overview of important mathematical ideas, such as logic, number theory, probability, statistics, and geometry. We have introduced new course components, including PowerPoint slides to guide class and a Personal Response System, in an effort to motivate students. In the LAM course,

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we have large numbers of students (usually around 200 students in each class), so we also use the WebCT Vista course management system for several aspects of the course, including homework and laboratories.

Throughout the class there are 10 computer laboratory assignments that students complete outside of class. These assignments take material from the course and extend it to new situations. For example, students seem particularly enthusiastic about a laboratory linking math and the television show *The Simpsons*. Another popular lab is based on how statistics can be deceiving. Many of the labs use online java applets to explore the material in a hands-on way; other labs can be completed on paper. In each lab there is also an essay question on the topic.

While several of the current labs are popular, we are always on the lookout for new topics that could be used in labs, especially topics that would particularly interest the students. Sudoku puzzles have started popping up everywhere (see (Wilson 2006) and web references for more information), including in our school newspaper. The link between logic and solving Sudoku puzzles seemed like a perfect opportunity to introduce a lab on this topic. We also felt that this lab was a good opportunity for the students to employ reasoning and proof, to communicate about mathematics, and to recognize mathematics in something they encounter outside of class, all of which are encouraged by the *Principles and Standards*.

The *Principles and Standards* also recommend that we encourage students to take more mathematics and that we help students see how mathematics is necessary to being an informed citizen. It is hoped that activities such as the one described here can help achieve these goals, while helping students see this basic mathematics course as

something more than just another requirement to be fulfilled. Some positive evidence from student work and surveys is included in this article.

The Activity

You may have seen *Sudoku* puzzles in lots of places -- on TV, in newspapers, or in magazines. In such puzzles, you have a 9x9 grid which is divided further into 9 3x3 sub-grids. The object of the game is to fill in the numbers 1-9 so that each number appears exactly one time in each row, column, and 3x3 sub-grid.

First we will play a simplified version of Sudoku, using a 4x4 grid divided into four 2x2 sub-grids. The puzzle has been solved when the numbers 1, 2, 3, and 4 appear exactly once in each row, column, and 2x2 sub-grid of the bigger grid. Puzzles vary in difficulty depending on how many numbers are already filled in when you start. In this lab, we are going to develop techniques to solve the puzzle in [figure 1](#).

1	4		2
4	3		1
	1	4	

Figure 1 Sudoku Puzzle

Question 1: One technique is to look for a row, column, or 2x2 sub-grid that has all but one number filled into it. Then you know whatever number is missing must go in the empty square. [Figure 2](#) gives the same puzzle, with the empty squares labeled with the letters a through h. Using the method described above, for which squares can you immediately see what number must go into them?

1	4	a	2
b	c	d	e
4	3	f	1
g	1	4	h

Figure 2 Sudoku Puzzle for Question 1

Question 2: Fill in the numbers that must go in the squares you marked for Question 1. For this particular puzzle, you can now repeat what you did before -- again find a row, column, or 2x2 sub-grid with only one number missing, and fill in that square with the missing number. Use this method as many times as needed to solve the puzzle.

Question 3: In some Sudoku puzzles, the techniques described in the previous two questions will not work. This is because you may start out with a puzzle that does not have *any* row, column, or 2x2 sub-grid that is missing all but one number. In this case, you have to consider what numbers are *possible* for a given square, and rule out all but one of those possibilities.

For example, in the puzzle in [figure 3](#), we see that the square marked "a" is in the first row of the grid. The first row already has a 1 and a 2, so we can conclude that square "a" must be a 3 or a 4 but we don't know which one. *However*, this square is also in the second column of the grid. We see that the second column already has a 1 and a 4 in it, so this tells us that square "a" must be a 2 or a 3. Since both conditions must be satisfied, we see that there must be a 3 in square "a" of the grid.

1	a	b	2
c	4	3	d
4	e	f	3
g	1	2	h

Figure 3 Sudoku Puzzle for Question 3

Once you figure out one square (as we did for square "a"), you can often use the techniques we used in Questions 1 and 2 to fill in the rest of the puzzle. Use any method you like to fill in the rest of the puzzle in [figure 3](#).

Question 4: The smaller the number of squares you are given already filled in, the more challenging a Sudoku puzzle is. Use any technique you can to solve the puzzle in [figure 4](#). Note you may have to use the method from Question 3 multiple times.

a	b	c	d
1	e	f	2
g	4	3	h
i	j	2	k

Figure 4 Sudoku Puzzle for Question 4

Question 5: As mentioned earlier, Sudoku is often played on a 9x9 grid which is divided up into 9 3x3 sub-grids. In order to solve such a puzzle, you want the numbers 1-9 to appear exactly one time in each row, column, and 3x3 sub-grid. Similar methods to the ones we discussed for solving 4x4 Sudoku puzzles can be used to solve a 9x9 puzzle. Use any methods you can think of to solve the 9x9 Sudoku puzzle in [figure 5](#).

5	3	a	b	7	8	9	1	c
6	d	2	1	9	5	3	e	8
f	9	8	3	g	2	5	6	h
8	5	i	j	6	1	k	2	3
4	l	6	8	m	3	7	9	1
7	1	n	9	2	o	p	5	6
9	6	q	5	r	7	2	8	s
t	u	v	4	1	9	6	w	5
3	4	5	2	8	x	1	7	9

Figure 5 Sudoku Puzzle for Question 5

Question 6: A 9x9 Latin Square puzzle is also played on a 9x9 grid, and is similar to a Sudoku puzzle. A 9x9 Latin Square puzzle is solved when the numbers 1 through 9 appear exactly one time in each row and column, but we drop the condition that each number must appear exactly once in each 3x3 sub-grid. Do you think solving a Latin Square puzzle would be easier or harder than solving a Sudoku puzzle? Explain your answer.

Student Work and Survey Results

In February of 2006, we gave students an opportunity to complete the Sudoku lab on WebCT. This lab could easily be completed on paper, although to improve the activity, you might consider incorporating some Sudoku java applets that are available online. Since we were piloting the lab, it wasn't a class requirement, but we offered it for a small amount of extra credit.

The students were given until April to complete the activity. It seems worth noting that, in comparison with the number of students completing the required lab assignments, a good number of students completed this extra credit assignment. This fact is especially interesting given that a fair number of students enrolled at the beginning of the course that complete the first few assignments eventually drop the course. For example, in the Spring 2006 semester, approximately 17% of students who were enrolled at the beginning of the semester had more than 17 absences out of the 35 total classes. The number of students completing the lab assignments is given in [table 1](#).

Lab Number	Number of Students Completing the Lab
1	405
2	377
3	381
4	341
5	356
6	319
7	324
8	306
9	291

10	300
11: Extra Credit Sudoku Lab	335

Table 1 Number of Students Completing Labs

The first five questions of the lab were graded strictly for correctness. The solutions to the two 4x4 and the 9x9 Sudoku puzzle discussed in these questions appear in [figure 9](#) at the end of the paper. For the final question, the students were graded on a 5 point scale using a rubric that is used to grade the essay question in each lab assignment. Students who gave well-written intelligent responses, regardless of which type of puzzle they thought would be easier to solve, were given full credit. Some quotes from student answers to the essay question are given in [figure 6](#).

Do you think solving a Latin Square puzzle would be easier or harder than solving a Sudoku puzzle?

“Harder. it is more difficult to rule out possibilities.”

“I think it would be easier simply because there is one less condition that must be accounted for when solving the puzzle. You just simply would not have to worry about that condition, so I think it would make it easier to solve.”

“A Latin Square Puzzle would be harder to do. In the Sudoku puzzle the 3x3 subgrid helps you determine what numbers are needed.”

Figure 6 Quotes from Student Work on Question 6

At the end of the semester, the students were given an anonymous survey about the activity. It is difficult to measure some concepts asked about on the survey, such as attitude toward the class. However, instructors may find some of this information useful in a practical way, so we have included the survey results. Two hundred students completed at least some questions on the survey. Among students participating in the

survey, 176 completed the Sudoku lab and 82% of these students said they enjoyed it. Of the students completing the lab, 81% said they had heard of Sudoku, although not many said they completed the puzzles often, prior to the lab. The frequency of completing Sudoku puzzles before and after the lab is compared in [figure 7](#).

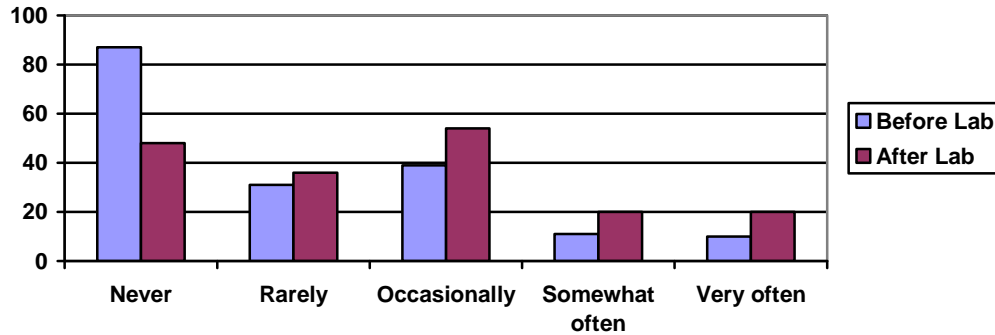


Figure 7 How Often Students Completed Sudoku Puzzles

The students were also asked if their feelings toward the class had changed after completing the Sudoku lab. The results from this question are given in [table 2](#).

How do feel about the class after completing the Sudoku lab?	Number of Students
I feel less positively.	6
I feel the same.	146
I feel more positively.	25

Table 2 Feelings Toward the Class After Completing the Sudoku Lab

The final survey question asked the students how the Sudoku lab could be improved.

Some quotes from student responses to this question are given in [figure 8](#).

Do you have any suggestions for how to improve the Sudoku lab?

“have different levels of difficulty for more points”

“make it easier to view and fill in the answers on the computer”

“have more Sudoku labs”

“a little harder”

“make it longer”

“No. It was fun how it was.”

Figure 8 Suggestions for Improving the Sudoku Lab

Conclusion

Because of survey results and student work, we generally feel that the Sudoku lab was successful. It is important, however, to continue to use, improve, and study the lab in future semesters to validate this result. In addition to incorporating java applet technology, we plan to offer some variations to the essay question. One essay question in consideration is, “Does a Sudoku puzzle with at least one solution always have a unique solution?” Based on responses from the survey, we may also include questions on some advanced techniques for solving more challenging Sudoku puzzles. We feel that LAM will always be a course in transition. We need to continue to allow the students to teach us what is important to them and what they really need to be successful in life. As the world changes, so too will Liberal Arts Mathematics.

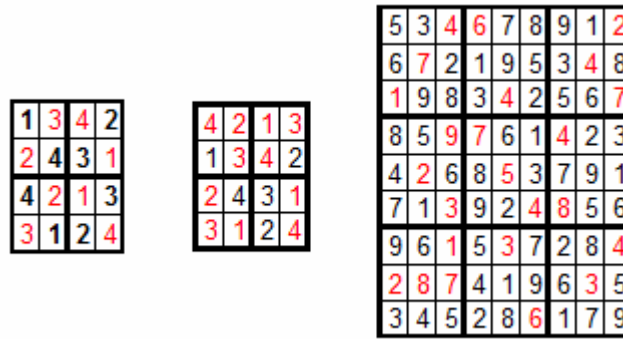


Figure 9 Solutions

References

Wilson, Robin. "The Sudoku Epidemic." *Focus* 26 (January 2006): 5-7.

National Council of Teachers of Mathematics (NCTM). *Principles and Standards for School Mathematics*. Reston, VA: NCTM, 2000.

A sampling of websites offering online Sudoku puzzles or more information on Sudoku (all accessed on July 10, 2006):

<http://www.websudoku.com/>

<http://www.sudoku.com/>

<http://www.dailysudoku.com/sudoku/index.shtml>

<http://en.wikipedia.org/wiki/Sudoku>

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