UNIVERSITY OF THE PHILIPPINES

Bachelor of Science in Applied Physics

Clarence Ioakim T. Sy

Learning dynamics in a cellular automata model of classroom peer-to-peer interactions

Thesis Adviser:

Johnrob Y. Bantang, Ph.D.

National Institute of Physics

University of the Philippines Diliman

Date of Submission:
June 2024

Thesis Classification:
F

National Institute of Physics
College of Science
University of the Philippines
Diliman, Quezon City

ENDORSEMENT

This is to certify that this thesis entitled **Learning dynamics in a cellular automata model of classroom peer-to-peer interactions**, prepared and submitted by Clarence Ioakim T. Sy in partial fulfillment of the requirements for the degree of Bachelor of Science in Applied Physics, is hereby accepted.

JOHNROB Y. BANTANG, Ph.D.
Thesis Adviser

The National Institute of Physics endorses acceptance of this thesis in partial fulfillment of the requirements for the degree of Bachelor of Science in Applied Physics.

WILSON O. GARCIA, Ph.D.
Director
National Institute of Physics

To thinking complexly

Acknowledgments

I would like to thank...

My family, for making sure I don't have to think about more things than I have to throughout my learning years, even in college. Thank you also for always providing more than what I need, and sometimes even more than what I want. I couldn't have afforded to be so carefree without you.

Dr. Johnrob Bantang, my adviser, for your patience, understanding, and guidance, for often treating us with food, and for the corniest and nerdiest jokes.

The Complexity Science Group. Reinier: for always being someone we can rely on and relate with. Laya and Sara: for making sure I felt at home with the group, especially when I first joined. Jeruine: for all the times we were lost together, both in class and in research, but figured things out one way or another.

The Flahtotoys, who are always there to support me with whatever problems I have, to share in my nerdy enthusiasm, and to go on so many adventures with. Special thanks to Hanzel who would come to my rescue even at such short notice. Life would not be as fun or tolerable if I hadn't met you all.

Julia, for believing in me and for appreciating me simply for who I am, flaws and all. Thank you for doing your very best to always be there for me, for always being patient and understanding with me, and for always being proud of me no matter what mistake I make.

Janella, for always matching my energy when I talk about literally anything, and for being someone I can confide in without fear of judgement.

The Hexagon, Matt and Darwin, for being the constants that you are since we met and for being people I can talk to about my problem(set)s, with topics ranging from electrodynamics and quantum mechanics to where we'll be eating lunch. You have helped me stay sane and have been constant reminders that there's much joy in being nerds together, even if what we end up talking about isn't remotely nerdy.

Ms. Danielle Buenaventura, for being someone I can talk to about my problems, and for being someone who can give me advice on how to deal with them.

The 401 tambays, Belle, Eli, Edneil, and Mika, for always being there to keep me company when I don't feel like going home for the day yet, and for inviting me to your occassional lakwatsas.

The Stephenian Scout Group, for always welcoming me back to a place where I can do what I enjoy outside the academe. Marc: for being someone I can turn to for knowledge and wisdom about the so many interests we share. Sid, Francynne, Chester, Kim, and Sam: for always being supportive and being g for the most random galas.

The Cakes, for being people I can talk about the latest meta and math for our favorite gacha games, and for sharing the struggles of being college students even if we're all in different schools.

Monica, for being unfathomably patient and supportive when I needed someone to be just that.

I can't list them all, but none of what any of you have done goes unappreciated. From the bottom of my heart, thank you.

ABSTRACT

LEARNING DYNAMICS IN A CELLULAR AUTOMATA MODEL OF CLASSROOM PEER-TO-PEER INTERACTIONS

Clarence Ioakim T. Sy
University of the Philippines (2024)

Adviser:
Johnrob Y. Bantang, Ph.D.

Peer-to-peer instruction has recently become one of the popular means of classroom instruction in Physics Education. Such educational setup must involve not only physical interaction with things but also actually doing some procedural steps mentally or physically. In this study, we investigate the effects of different seating arrangements to the students' learning efficiency in the peer-to-peer mode of instruction by modelling the transfer of knowledge within the class. We compared the efficiency of learning between the traditional learning model and peer-to-peer learning model. We found that in square classrooms with different lengths $L \in \{32, 48, 64, 96, 128\}$, the inner corner seating arrangement performed the best among the peer-to-peer learning setups in terms of both the time it takes to saturate the classroom with learned students (t_{max}) and the classroom's learning rate (m). This result is different from a previous studies. The difference stems from the simplifications made in this model that may not reflect real world factors. Our model uses binary values instead of continuous values as a measure of students' aptitude, does not consider memory or unlearning and directionality or orientation bias (non-isotropy). It also does not consider the similarity effect mentioned in related literature where peer discussion can enhance understanding even if none of the students knows the correct answer. However, despite these simplifications, we found that in smaller classrooms with slow learners, peer-to-peer learning is more efficient compared to the traditional learning model, just as previous studies has suggested.

Taken from SPP-2024 paper

PACS: 01.20.+x [Communication forms and techniques (written, oral, electronic, etc.)], 01.30mm (Textbooks for graduates and researchers)

Table of Contents

List of Figures

Chapter 1

Peer Instruction and The Traditional Models of Teaching

something

1.1 History of Peer Instruction

Something something Mazur something something

1.2 Difference of Peer Instruction from Traditional Models

1.2.1 Details of Peer Instruction

1.2.2 Benefits of Peer Instruction

1.2.3 Drawbacks of Peer Instruction

1.3 Numerical models for learning in the classroom

Chapter 2

The Classroom as a Binary Probabilistic Cellular Automata Model

The classroom is a complex system that can be modeled as a probabilistic cellular automata. This chapter will discuss the classroom as a complex system and the probabilistic cellular automata model. The chapter will also discuss the implications of the model on the classroom and the teaching-learning process. (AI Generated Text)

2.1 What is a cellular automaton and why use is to model a classroom?

Things to discuss (see Reinier's MS for help):

- Lattice neighborhood: von Neumann, Moore, etc.
- Boundary conditions: toroidal, spherical, fixed, etc.
- Transition rules: deterministic, probabilistic, etc.
- Update rules: synchronous, asynchronous, etc.
- Other factors considered: Inhomogeneous individual learning rate
- Other factors not (yet) considered: Anisotropy, similarity effect, memory/unlearning

2.2 The binary probabilistic cellular automata model for a peer instruction classroom set up

- Governing equation:

$$P_{ij} = 1 - \prod_{\forall \delta i, \delta j} [1 - (\lambda_{ij})(\rho_{i+\delta i, j+\delta j})(s_{i+\delta i, j+\delta j})] \tag{2.1}$$

where:

$P_{ij} \in [0,1]$ is the probability of the student seated in row i and column j to learn,

$\lambda_{ij} \in [0,1]$ is the learning rate of the student in row i column j,

$\rho_{ij} \in [0,1]$ is the probability the student in seat i, j to learn from the students in seat $i + \delta i, j + \delta j$, and

$$s_{i+\delta i, j+\delta j} = \begin{cases} 1 & \text{if the student in seat } i + \delta i, j + \delta j \text{ is learned} \\ 0 & \text{if the student in seat } i + \delta i, j + \delta j \text{ is not learned} \end{cases}$$

- Other relevant rules:
  - Seating arrangement chosen from the following: Inner corner, outer corner, center, and random [2]
  - Simulation is considered done when all students are learned

2.3 The binary probabilistic cellular automata model for a traditional classroom set up

- Governing equation:

$$P_{ij} = \lambda_0 \tag{2.2}$$

where:

$P_{ij} \in [0,1]$ is the probability of the student seated in row i and column j to learn,

$\lambda_0 \in [0,1]$ is the probability of the student i, j to learn from the teacher

- Other relevant rules:

1. All students are unlearned at the start of the simulation.
2. Simulation is considered done when all students are learned.

2.4 Results: PI vs Traditional

- List of input and output parameters?
- m vs λ or ρ_0
- t_{max} vs λ or ρ_0
- t_{max} vs N for specific λ or ρ_0
- Comparison between levels of homogeneity of learning rates

2.5 Discussion/conclusions?

1. The traditional learning model is more scalable. Between the same ρ, the power law exponent b is lower than its peer-to-peer counterpart.
2. Inner corner configurations have higher b-values, while the traditional configurations have lower b-values.
3. B-values generally increases with ρ values
4. Intersections where PI is more efficient occur at lower class sizes and lower ρ values.
    - In some class sizes, traditional and P2P approaches can become equally efficient depending on the learning rate ρ.
5. Similar finding with previous research [1]: Students with less background knowledge learned as much with PI as students with more background knowledge with traditional instruction.

Chapter 3

Customized Chapter

This is a customized chapter.

3.1 First section

You may change the filename of this file as long as you correspondingly change the filename stated in the `input{}` line in the `main.tex`.

3.2 Including figures

Figures can be added into your LaTeXfiles using the `figure` environment. However, it is **recommended** that you use `.eps` file format. These are encapsulated postscript files. This can be easily done by installing a postscript printer that outputs to a file (port is FILE). Ask your system administrator to install such a device for producing `eps` files by simply printing it to that device.

Shown in Fig. 3.1 is a figure created from Excel®. Note that the bounding box and page bounding box should be adjusted well enough to show the correct field.

Please see the sample chapter on how the figure is included in the `tex` files.

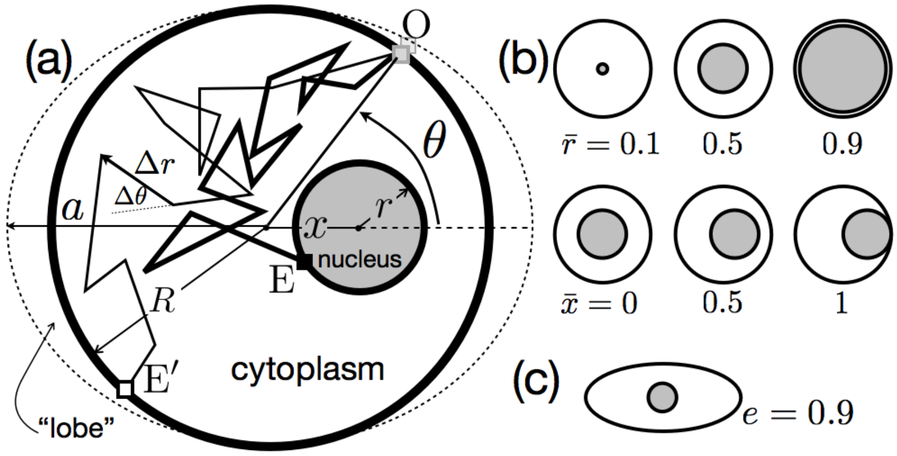

Figure 3.1: A *.png file.

Chapter 4

Another Customized Chapter

In this chapter, a sample for making equations and sub-equations are demonstrated.

4.1 Equations and sub-equations

In the following, a set of equations is shown.

$$\vec{\nabla} \cdot \vec{D} = \rho \tag{4.1a}$$

$$\vec{\nabla} \cdot \vec{B} = 0 \tag{4.1b}$$

$$\vec{\nabla} \times \vec{E} = -\partial_t \vec{B} \tag{4.1c}$$

The last one being

$$\vec{\nabla} \times \vec{H} = \vec{J} + \partial_t \vec{D} \tag{4.1d}$$

Note that text can still be placed between sub-equations within the `subequations` environment.

When using a solitary equations, you may use the usual equation syntax in LaTeX.

$$E = mc^2 \tag{4.2}$$

Chapter 5

Summary and Conclusions

A short sample thesis/dissertation is presented. Although not complete, it will be useful for newbies in LaTeX. Any questions? email me at the following address: `johnrob.bantang@gmail.com`.

Appendix A

Sample appendix

This gives an example of an appendix chapter. Note that this file has been included **after** the line `\appendix` in `main.tex`.

A.1 Equations in appendix

You don't need to worry about equations within the appendix since LaTeXautomatically formats the equation numbers for you. For example,

$$c^2 = a^2 + b^2 \tag{A.1}$$

becomes the Pythagorian theorem where c is the length of the longest side of any right triangle.

A.2 Codes as appendix

Include your codes when necessary to your thesis/dissertation. To do this, you may use `verbatim` environment as follows. **WARNING:** All verbatim and verbatiminput environments should always be treated as a separate paragraph. When included in a text paragraph, it sometimes happen to reduce the 1.5 spacing to the usual single-spaced text.

```
#include <iostream>
using std::cout;
using std::endl;

int main( void )
{
   cout << "Hello world!" << endl;
   return 0;
}
```

The {\small } bracketed region is used to lower the font size of the entire verbatim text. This will save you much space and give a more aesthetical look in your manuscript.

On the other hand, when very long codes are wished to be included automatically without the tedious cut and paste procedure, you may include them using the \verbatiminput command as follows. You may want to include a short description of the code of course.

```
//Johnrob Y. Bantang, Natinal Institute of Physics
//Created: 03 October 2002
// Makes new C files
// usage: newC filename
//Modifications:
// >> 21 Jan 2003, Johnrob
//   included the constant AUTHOR and AFFILIATION for portability

#include <stdlib.h>
#include <iostream.h>
#include <fstream.h>
#include <strstream.h>
#include <time.h>
#include <string.h>

const char *const AUTHOR= "Johnrob Y. Bantang";
const char *const AFFILIATION= "National Institute of Physics";
const char *const EXTENSION= ".cpp";

int main(int argc,char **argv){
if(argc!=2){
cout<<"usage: newC filename"<<endl;
exit(0);
}
char *fname= new char[strlen(argv[1])+5];
ostrstream out(fname,strlen(argv[1])+5);
out<<argv[1]<<EXTENSION;
time_t date=time(NULL);

ofstream file(fname,ios::nocreate,0);
//opens normal file that **already exists**;
if(file){
for(int i=1;i<5;i++)
cout<<"WARNING! file aready exists!"<<endl;
cout<<endl<<"you can type"<<endl<<endl;
cout<<"\t\"head "<<fname<<"\""<<endl;
cout<<"in command line to *view version*"<<endl<<endl;
cout<<"please enter 1 to OVERWRITE this file"<<endl;
```

```
cout<<"type anything to cancel"<<endl;
for(int i=1;i<5;i++)
cout<<"WARNING! file aready exists!"<<endl;
int n;
cin>>n;
if(n!=1){
cout<<"*no* file is created... exiting..."<<endl<<endl;
exit(0);
}
file.close();
file.open(fname);
if(!file)
cout<<"**cannot create new file!!**"<<endl;
cout<<"OLD FILE: "<<fname<<" *overwritten!*"<<endl;
}
if(!file){
file.open(fname);
if(!file){
cout<<"**cannot create new file!!**"<<endl;
exit(0);
}
cout<<endl<<"NEW FILE created: "<<fname<<endl<<endl;
}

cout<<"\tcreating contents for the new C++ file: "<<endl<<endl;
//creating headers...
file<<"//filename: \""<<fname<<"\""<<endl;
file<<"//"<<AUTHOR<<", "<<AFFILIATION<<endl;
file<<"//Created: "<<asctime( localtime(&date) );
//writes the time and date today; endl already in asctime();
file<<"//"<<endl;
file<<"//Comments:"<<endl;
file<<"// >>"<<endl;
file<<"//"<<endl;
file<<"//This file is generated using the \"newC generator\"..."<<endl;
file<<"//Modifications:"<<endl;
file<<"// >>"<<endl<<endl;
file<<"#include <iostream.h>"<<endl;
file<<"#include <math.h>"<<endl<<endl;
//starting the main body...
file<<"int main(int argc,char **argv){"<<endl;
file<<"//\tif(argc!= ...){"<<endl;
file<<"//\t\tcout<<\"usage: "<<argv[1]<<".exe ... \"<<endl;"<<endl;
file<<"//\t\texit(1);"<<endl;
file<<"//\t}"<<endl;
file<<"\t//write the main body here"<<endl;
file<<"return(0);"<<endl<<"}"<<endl;

delete fname;
```

```
  file.close();
  cout<<endl<<"\tCREATION SUCCESSFUL!"<<endl<<endl;
return 0;
}
```

This time, you may just include your recent codes by just copy-paste-ing the codes (as long they are clean!) into the directory `codes/` in the directory where this file is saved.

Bibliography

[1] Nathaniel Lasry, Eric Mazur, and Jessica Watkins. Peer instruction: From harvard to the two-year college. *American journal of Physics*, 76(11):1066–1069, 2008.

[2] RM Roxas, SL Carreon-Monterola, and C Monterola. Seating arrangement, group composition and competition-driven interaction: Effects on students' performance in physics. In *AIP Conference Proceedings*, volume 1263, pages 155–158. American Institute of Physics, 2010.