42nd Samahang Pisika ng Pilipinas Physics Conference
Batangas State University, Batangas City
03 July 2024

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

Clarence Ioakim T. Sy*, Reinier Xander A. Ramos and Johnrob Y. Bantang

Instrumentation Physics Laboratory
National Institute of Physics
University of the Philippines Diliman
*ctsy@up.edu.ph

Traditional instruction vs peer instruction

Traditional instruction	Peer instruction
The teacher delivers a lecture to the whole class for the duration of the class time.	Students are given the chance to learn from each other during class time after an initial lecture by the teacher.

Advantages of peer instruction (PI)

Improve students' conceptual understanding and problem-solving skills compared to traditional instruction

Benefit groups even if no one in it initially knew the answer

Students with less background knowledge learn as much as students with more background knowledge (vs traditional instruction)

N. Lasry, E. Mazur, and J. Watkins, Peer instruction: From harvard to the two-year college, Americanjournal of Physics 76, 1066 (2008).
M. K. Smith, W. B. Wood, W. K. Adams, C. Wieman, J. K. Knight, N. Guild, and T. T. Su, Whypeer discussion improves student performance on in-class concept questions, Science 323, 122 (2009).
C. H. Crouch and E. Mazur, Peer instruction: Ten years of experience and results, American journal of physics 69, 970 (2001).

Research questions

Learning rate

- How does the number of learned students develop over time?

Traditional vs peer instruction

- When is peer instruction better than traditional instruction?
- Which factors lead to a difference in performance?

Spatial position of high aptitude students in class

- How does the positioning of learned students affect the learning rate of the class for peer instruction?

The classroom as a binary probabilistic CA model

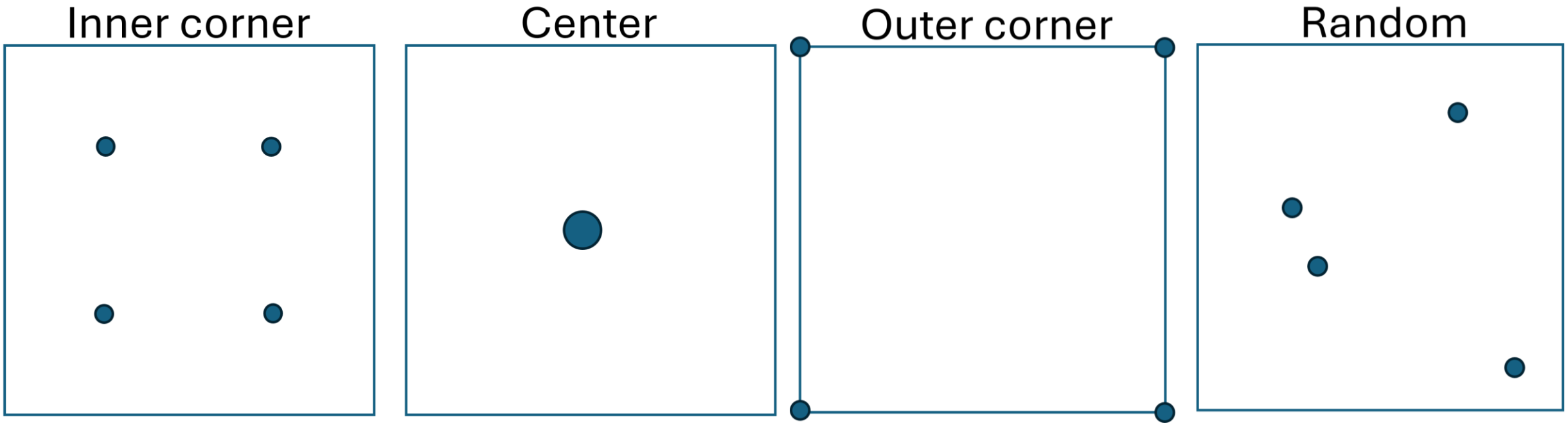
The classroom is set to be a **2D square grid** of varying lengths.

Students are either **learned or not learned.**

Simulations are initialized with 4 different seating arrangements (SA): **inner corner, outer corner, center, random.**

The simulation is considered done when all students are learned.

Different PI seating arrangements

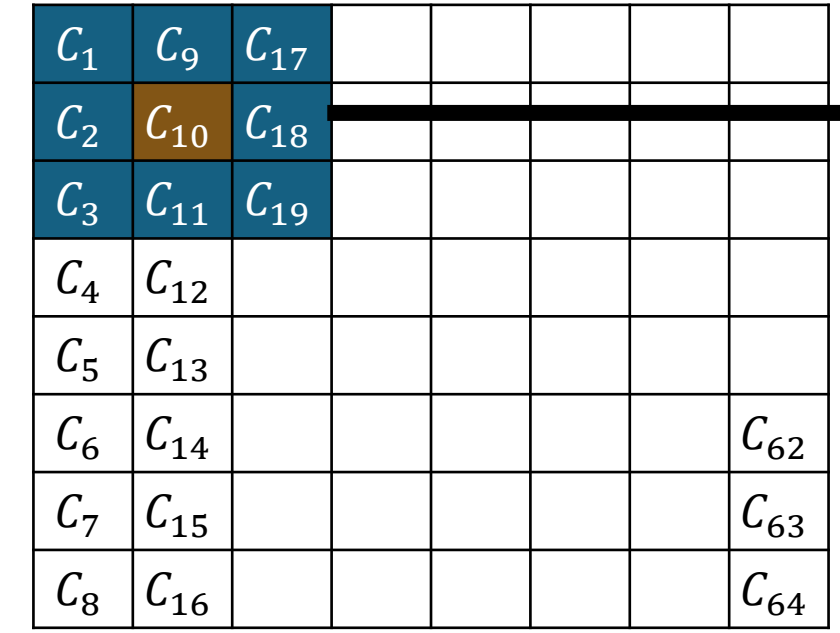


- Circles indicate location of learned students

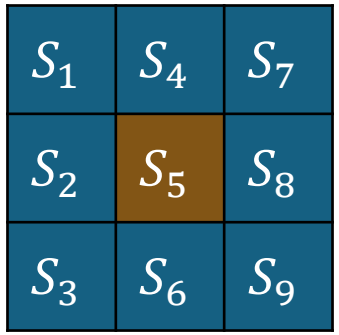
PCA rules for classroom simulation

	Traditional Instruction	Peer Instruction
Initial state of classroom	Starts with $n_0 = 0$ learned students	Starts with $n_0 = 4$ learned students. Different seating arrangements (SA): inner corner, center, outer corner, and random
Probability of each student learning	Equal to learning coefficient (λ_0). $P_i = \lambda_0$	Dependent on the learning coefficient (λ_0) and the number of learned neighboring students $P_i = 1 - \prod_{n \neq 5}(1 - S_n \lambda_n)$

Determining learning probability per time step

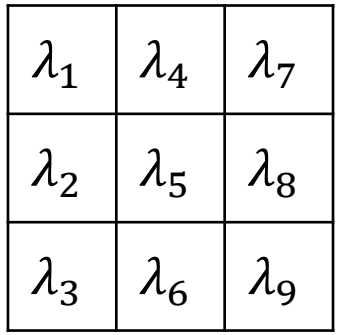


Classroom represented as lattice of cells



Neighborhood state of C_{10}

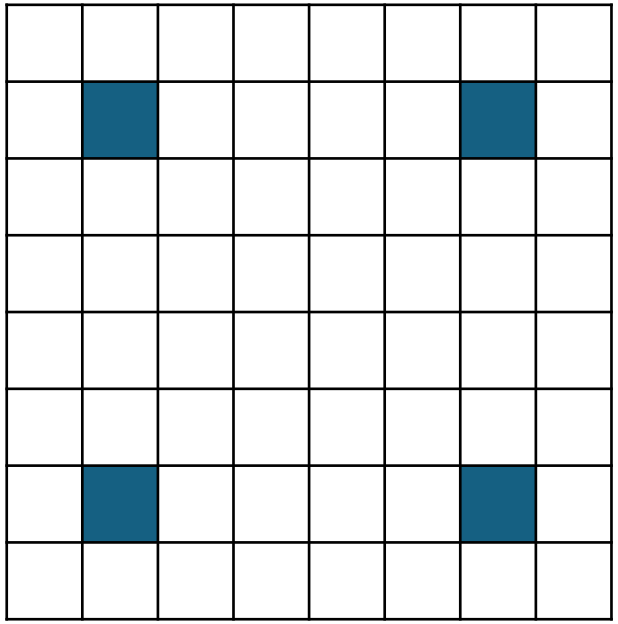
$\odot$



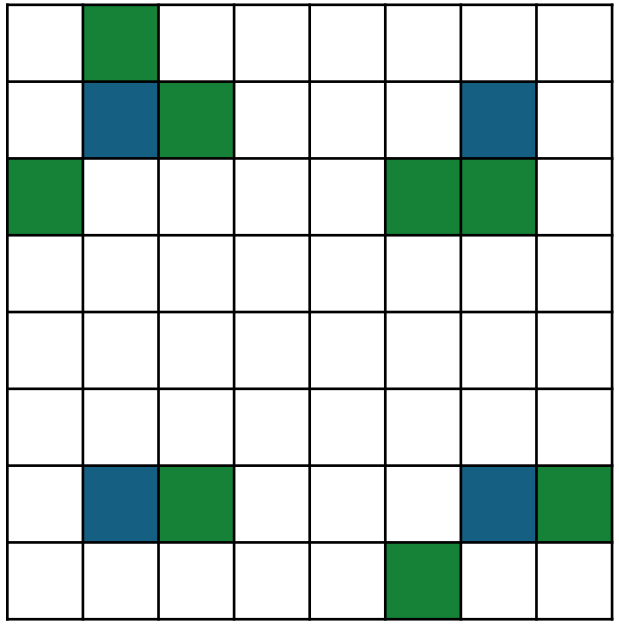
Learning coefficient matrix Λ

Learning probability: $P_i = 1 - \prod_{n \neq 5} (1 - S_n \lambda_n)$

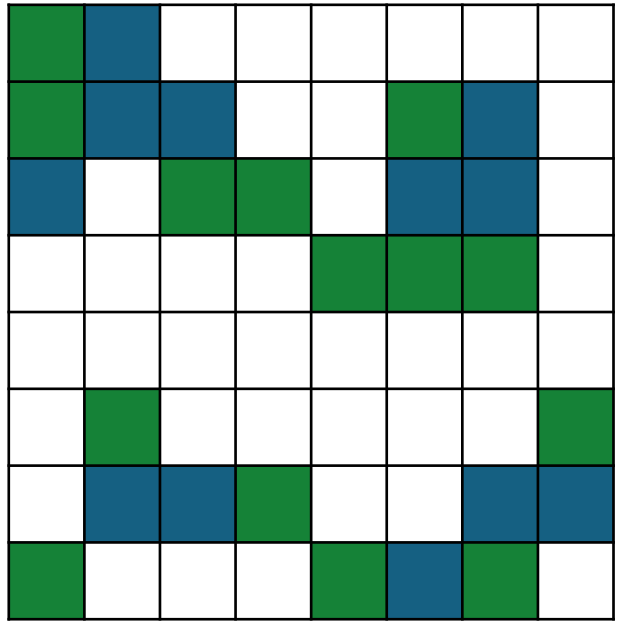
Sample progression of states



$t = 0$



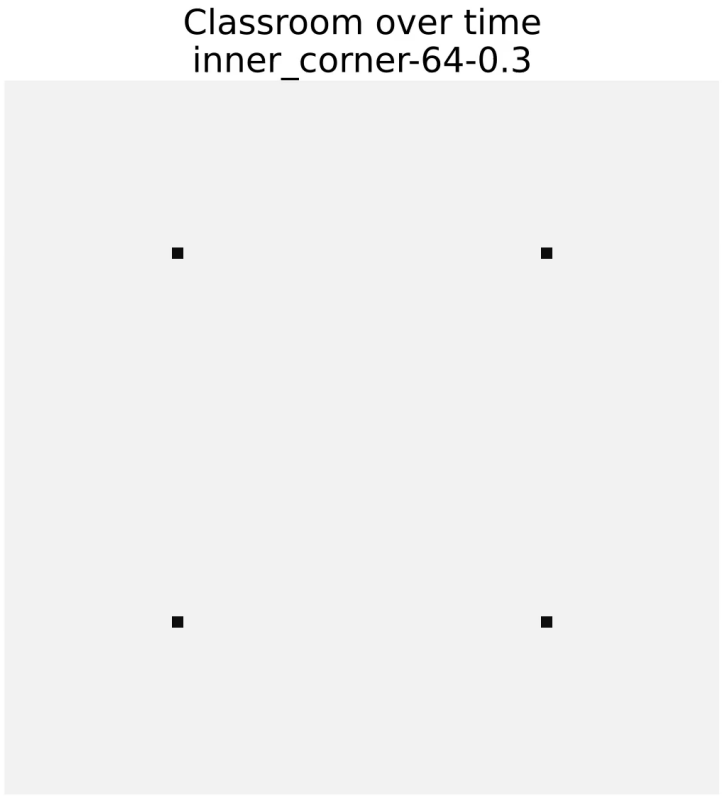
$t = 1$

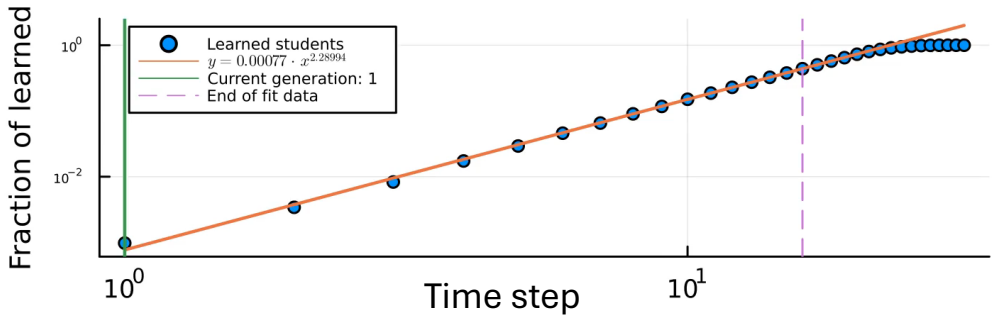


$t = 2$

Previously learned students

Newly learned students





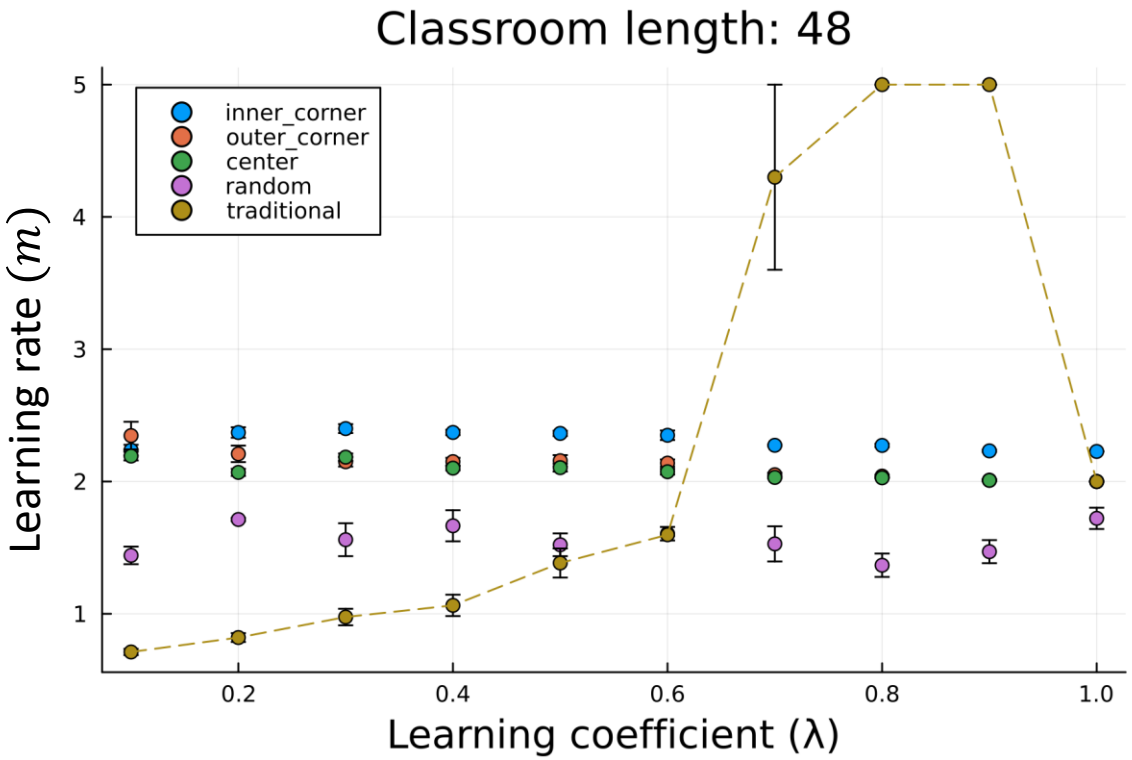
Learning rate (m):

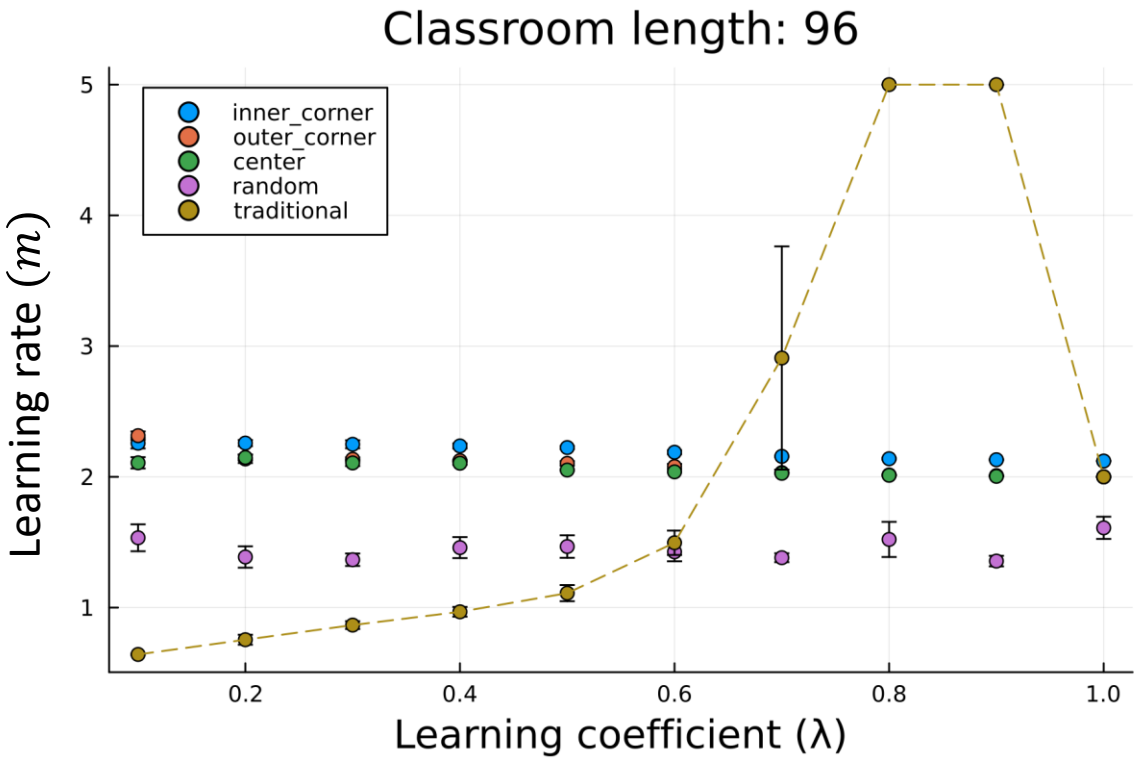
- fraction of learned $= at^m$

Time to learn (t_{max})

- Number of time steps for all students to learn

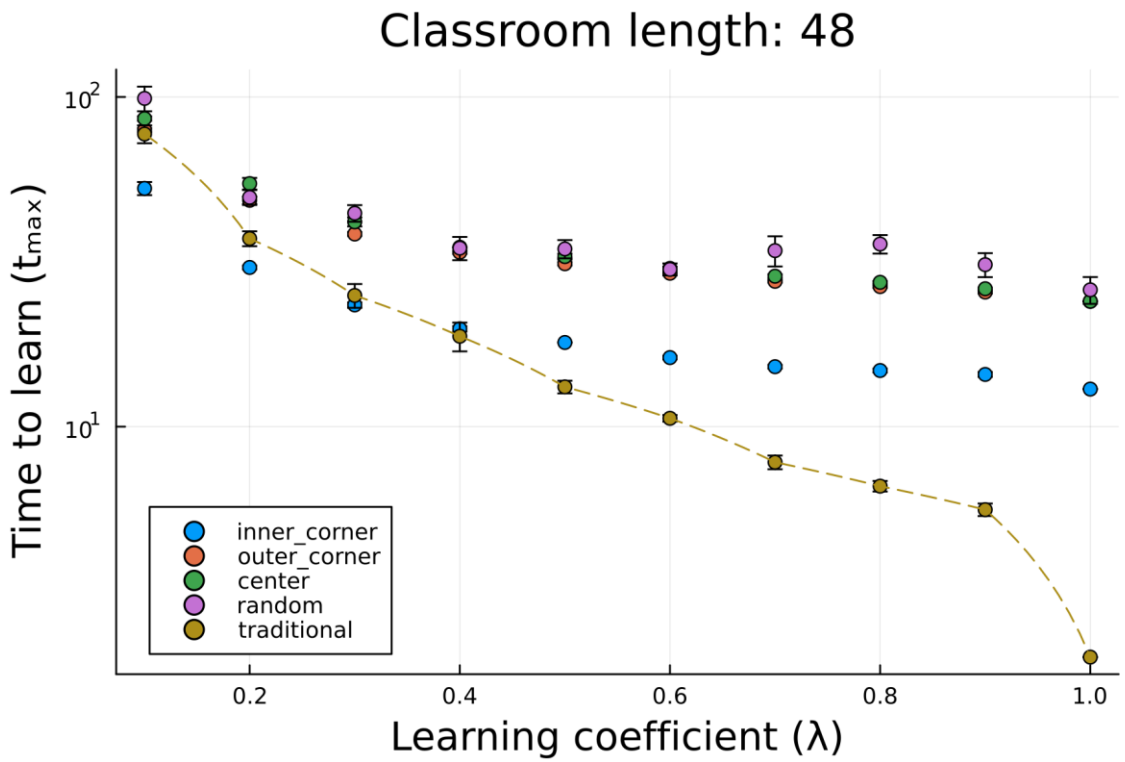
Class learning rate m with λ (higher is better)

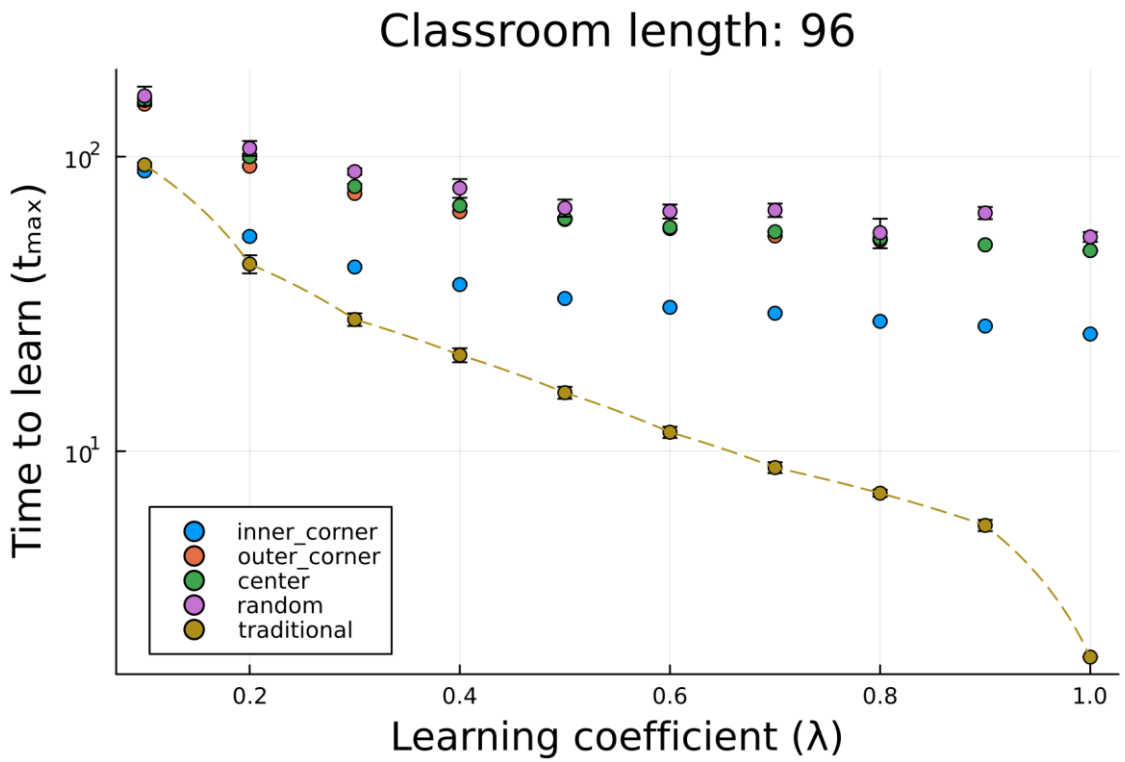




For smaller learning coefficients λ, classrooms using PI have higher learning rates compared to their traditional counterparts

Time to learn t_{max} with λ (lower is better)

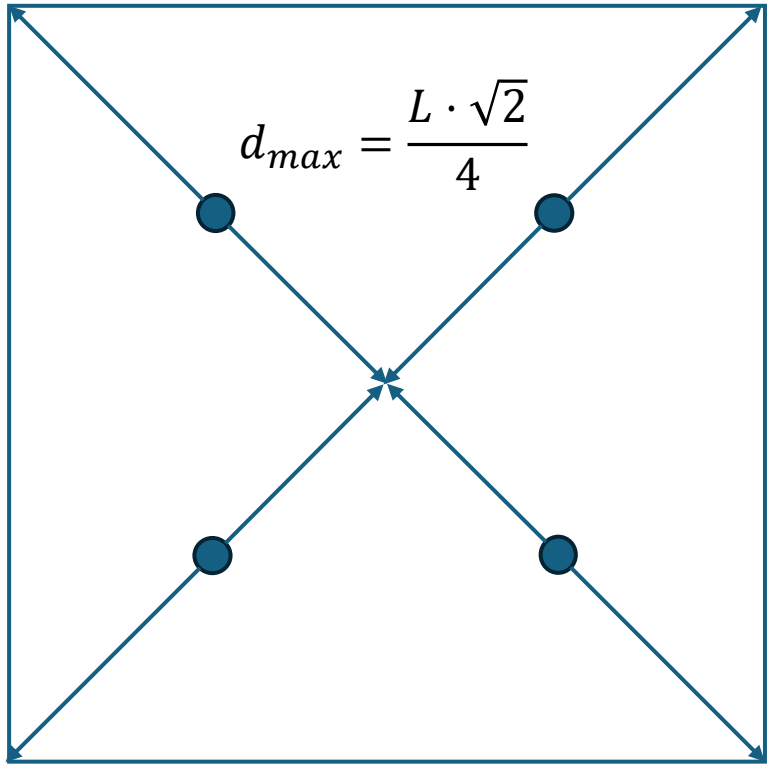




In smaller classrooms with small learning coefficients λ, the PI set-up can yield less time to learn compared to the traditional set up. In bigger classrooms, the traditional set ups are always better in terms of time to learn.

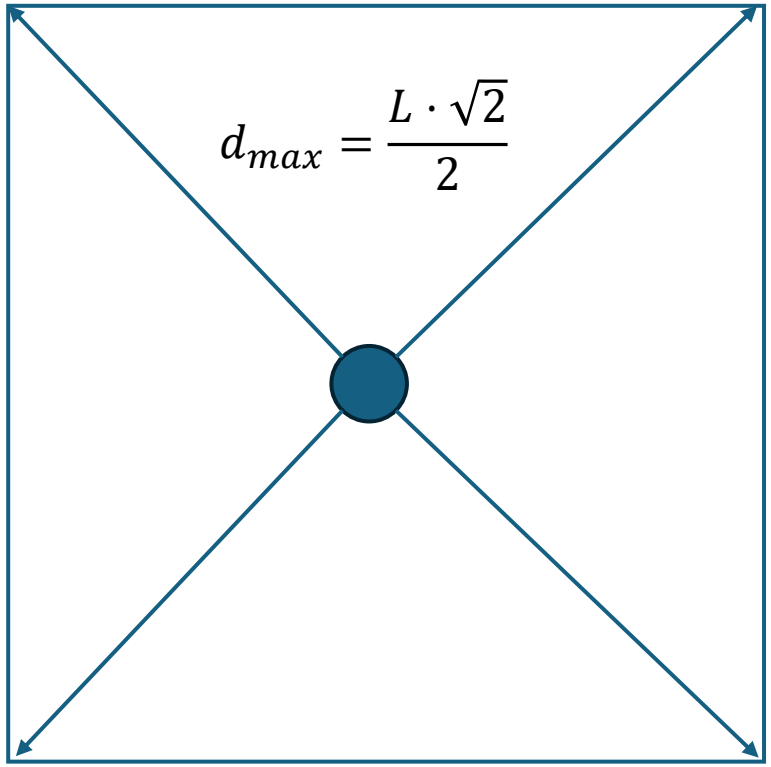
SA performance due to differences in d_{max}

Inner corner



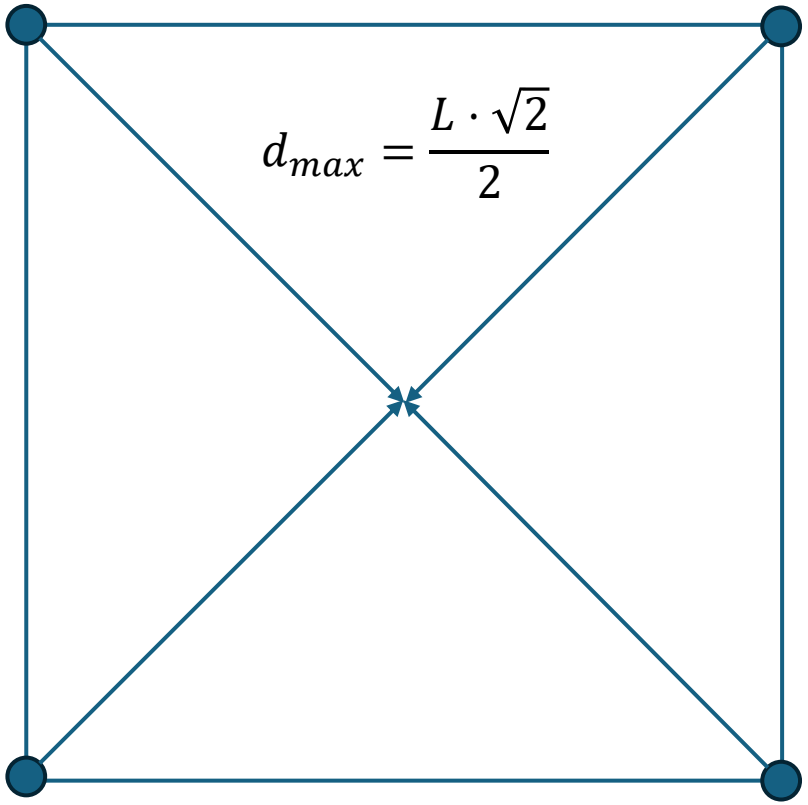
Shortest time to learn (t_{max})
Fastest learning rate (m)

Center



Longer time to learn (t_{max})
Slower learning rate (m)

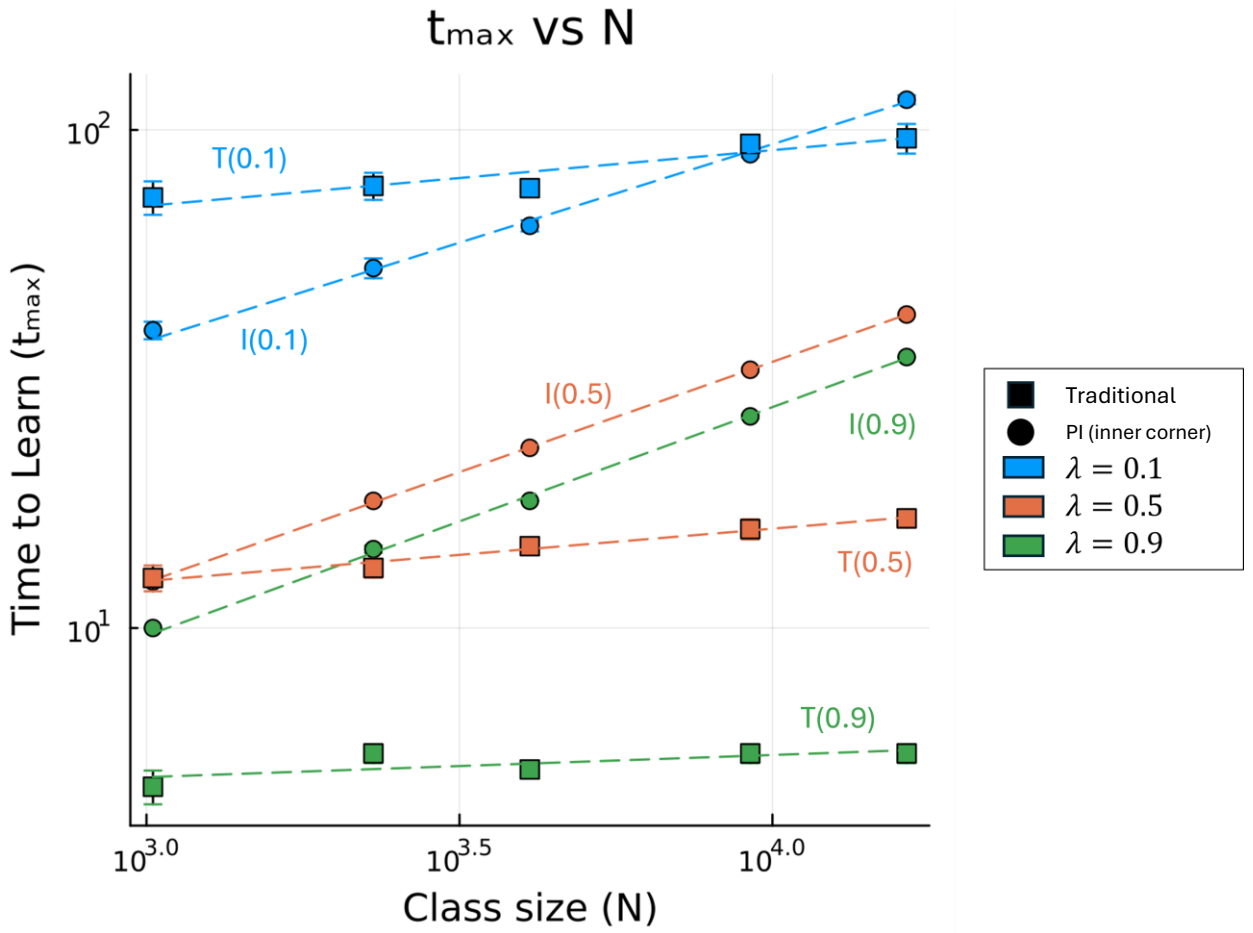
Outer corner



Longer time to learn (t_{max})
Slower learning rate (m)

Time to learn t_{max} with N (PI vs. Traditional)

For higher learning coefficient (λ), peer instruction starts to perform worse at higher class sizes

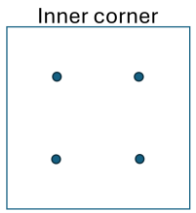


Conclusion

Traditional instruction is more scalable and is less dependent on class size.

Peer instruction (PI) performs better than traditional instruction for smaller classrooms with slow learners.

Among peer instruction seating arrangements (SA), the inner corner SA performs the best.



Similar findings with previous research: Students with less background knowledge learned as much with PI compared to students with more background knowledge with traditional instruction.

42nd Samahang Pisika ng Pilipinas Physics Conference
Batangas State University, Batangas City
03 July 2024

Thank you for listening!

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

Clarence Ioakim T. Sy*, Reinier Xander A. Ramos and Johnrob Y. Bantang

Instrumentation Physics Laboratory
National Institute of Physics
University of the Philippines Diliman
*ctsy@up.edu.ph

Derivation for learning probability

$$p + q = 1$$

$$\prod_{\forall e}(p_e + q_e) = 1$$

$$\prod_{\forall e}(p_e) + \cdots + \prod_{\forall e}(q_e) = 1$$

$$P = 1 - \prod_{\forall e}(q_e) = 1 - \prod_{\forall e}(1 - p_e)$$