Does classroom teaching of system dynamics concepts reduce correlation heuristic reliance? A case study from India

Presented by: Gitanshu Choudhary, Akash K Rao, and Varun Dutt

Introduction

- Stock-flow (S-F) knowledge is a fundamental and essential aspect of many real-life decisions (Cronin et al., 2009; Sterman, 2000).
- Tasks such as filling a bathtub, maintaining a bank account, and the earth's climatic system are all based on S-F principles (Sweeney & Sterman, 2000).
- Despite the pervasive nature of S-F problems, research indicates that people have issues understanding and solving them (Cronin et al., 2009).
- Inability to comprehend S-F principles leads to the use of wrong problem-solving techniques or heuristics, such as correlation heuristic (Cronin et al., 2009).
- Formal education fails to teach the basic S-F principles, and even propagate the use of correlation heuristic by encouraging students to use linear thinking (Cronin et al., 2009).

Introduction

- Therefore, there is a need to introduce S-F principles in the education system and develop a successful pedagogy of S-F principles to reduce reliance on inappropriate heuristics and problem-solving techniques.
- Motivated by the above points, this research aims to study the effects of a graduate-level system dynamic course on students' understanding of S-F relationships.

Background

- Prior literature suggests that learning from experience is an effective way of countering S-F failure and reducing reliance on the correlation heuristic (Kumar & Dutt, 2018).
- Furthermore, the improved understanding of the S-F relationship facilitated by experience can be transferred to solving S-F problems.
- In a study conducted by Sterman (2010), students were taught the basics of system dynamics. The experiment results revealed that the training provided in system dynamics improved participants S-F problem-solving skills and reduced their reliance on the correlation heuristic.
- Similarly, simulation tools like DCCS and Climate Rapid Overview And Decision Support (C-roads) have used prior training in a simulated environment to reduce people's reliance on correlation heuristic during the S-F task (Kumar & Dutt, 2018; Sterman et al., 2012).
- However, the discussed points have not been adopted in academic settings, especially in the developing world, particularly in top Indian educational institutes.

OBJECTIVES

- To analyze the effect of training and education on the proportion of correct responses for stock-flow problems.

- To analyze the effect of training and education on reliance on the correlation heuristic when attempting stock-flow problems.

COURSE OVERVIEW

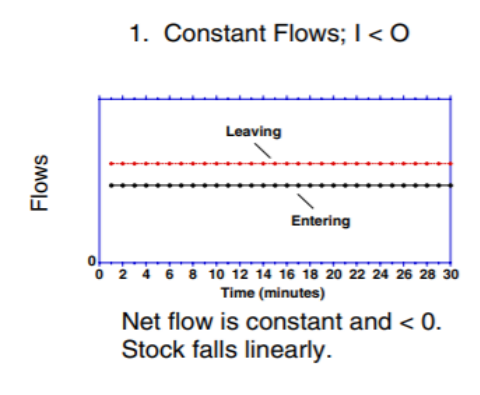
- Computational modeling of social systems (CMSS) course was offered during the 2019 spring semester at IIT Mandi.
- The objective of the course was to introduce students to statistical and system-dynamic approaches to modeling the behavior of simple and complex social systems.
- Emphasis was laid on highlighting the heuristics and biases in individual and group decisions and integrating those heuristic and biases assumptions in computational models of aggregate behavior.
- Concepts such as:
  - Dynamics associated with stocks and flows
  - Counterintuitive behavior of social systems
  - Learning and feedback processes
  - Causal loop diagrams

  were discussed and covered up until the mid-term point of the course.
- Post the mid-term point of the course. Participants were subjected to three S-F problems (task) to test their problem-solving skills for S-F problems.

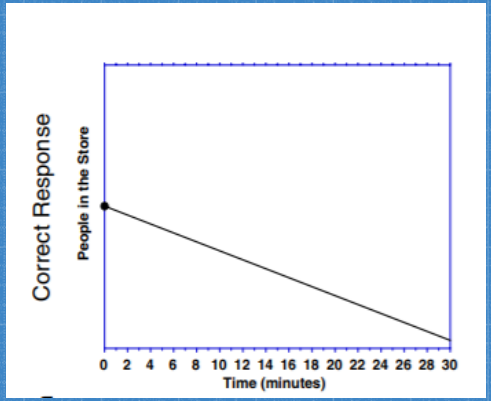
TASK

- The task consisted of three S-F problems taken from Cronin et al. (2009).
- The questions were designed to test the participant's understanding of accumulation principles and the extent of reliance on correlation heuristic.
- The task, termed as the "department store task," presented participants with a graph showing the number of people entering and leaving a department store each minute over a 30-minute interval (Cronin et al., 2009).
- Based on the graph, participants were asked to sketch the number of people in the store (Y-axis) over 30-minutes (X-axis).

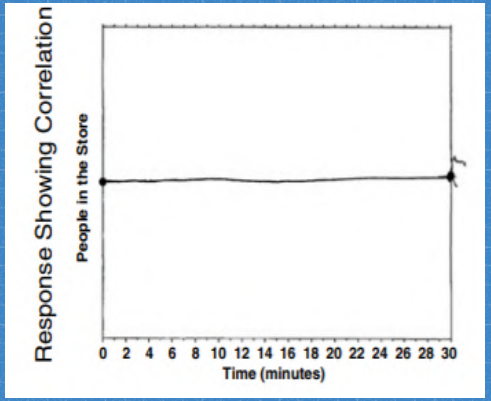
TASK (QUESTION 1)



- Pattern of the rate of inflow similar to the rate of outflow.
- Rate of outflow consistently higher than the rate of inflow
- Flows remained constant over time.

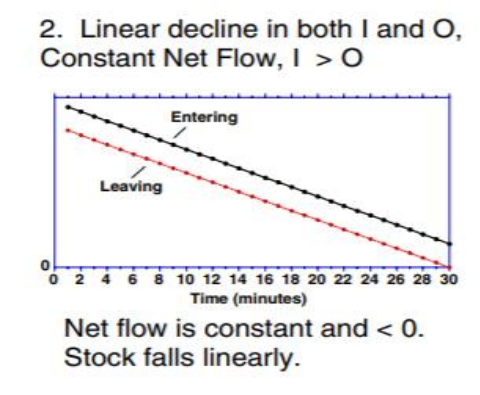


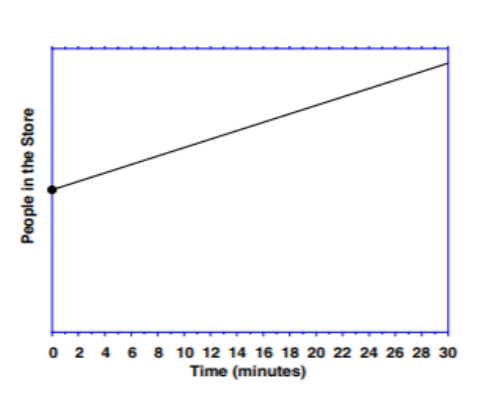
- Linear decline of the stock over time.

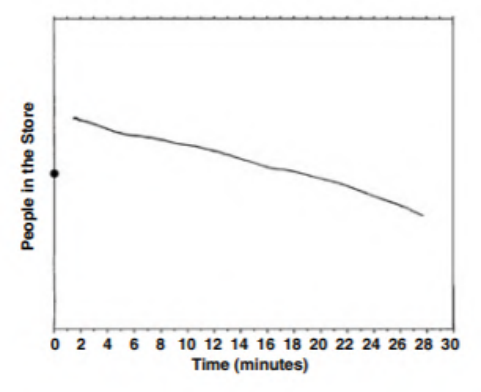


- However, on account of the correlation heuristic, constant flows might elicit a faulty perception on the participant's part that the stock might be constant over time.

TASK (QUESTION 2)





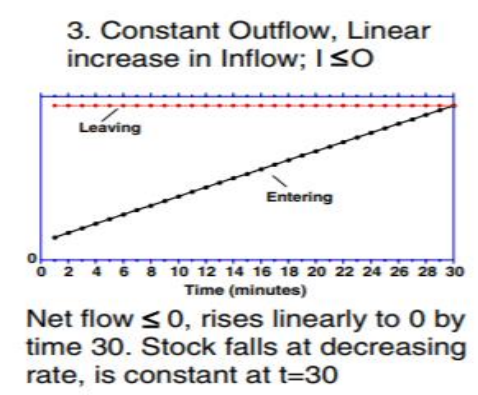


- Pattern of the rate of inflow similar to the rate of outflow.
- Rate of inflow consistently higher than the rate of outflow
- Flows exhibited a steady and linear decline over time.

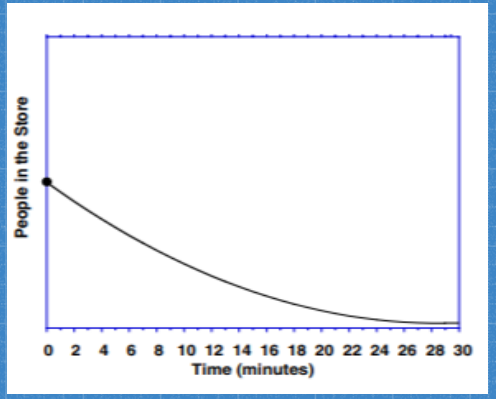
- Linear increase of the stock over time.

- However, on account of the correlation heuristic, a constant linear decline of flows might elicit a faulty perception on the participant's part that the stock might decline linearly over time.

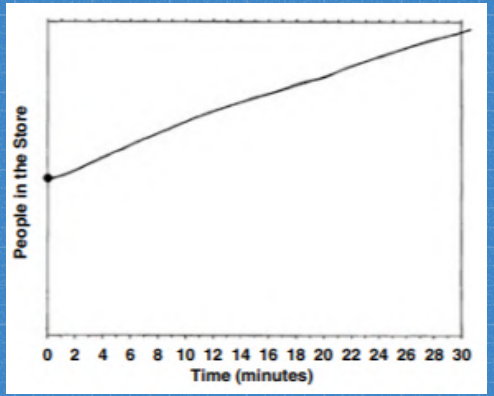
TASK (QUESTION 3)



- Pattern of the rate of inflow not similar to the rate of outflow.
- Linear increase in the rate of inflow, whereas the rate of outflow remained constant.
- The intensity of outflow remained higher than the inflow, and at the 30 minutes mark it was same.



- Fall of the stock at a decreasing rate over time.
- At the 30 minutes mark, when both the flows had the same rate, the stock became constant.



- However, on account of the correlation heuristic, the linear increase in the inflow coupled with the constant outflow might elicit a faulty perception on the participant's part that the stock would increase linearly over time.

EXPERIMENTAL DESIGN

- There were two between-subject conditions: experimental (N = 45) and control (N = 45)
- The experimental condition comprised of students enrolled in the CMSS course. Participants in the control group were not exposed to any of the CMSS course teachings.
- Thus, the independent variable was the training and learning provided in the CMSS course, and the dependent variable was the correctness of participants' responses.
- For the computational purpose, responses in both the condition were converted to codes.
- The correct responses were marked as 1, and the incorrect responses were marked as 0. Furthermore, incorrect responses exhibiting correlation heuristic were marked as 1, and incorrect responses not showing correlation heuristic were marked as 0.
- We performed 2 experimental conditions × 2 response outcomes, and 2 experimental conditions × 2 correlation heuristic chi-square tests to study the difference between the performance of the experimental group and the control group.

PARTICIPANTS

- A total of 90 participants across 2-between subjects condition (*n*= 45 in each condition) from the Indian Institute of Technology (IIT) Mandi, Himachal Pradesh, India, took part in this study.
- Average age = 21.3 years, SD = 1.45 years
- Gender: 29 females and 61 males
- All the participants were from a Science, Technology, Engineering, or Mathematics (STEM) background
- Participants in both the between subject conditions were given 30 minutes to answer the three questions.

RESULTS

- For question 2 and 3, the proportion of correct responses in the experimental condition were significantly greater than the proportion of correct responses in the control condition.
- For question 1 and 3, the proportion of incorrect responses exhibiting correlation heuristic in the experimental condition were significantly smaller than the proportion of incorrect responses exhibiting correlation heuristic in the control condition.
- Overall, there was a significant effect of training and education in improving participant's performance and reducing their reliance on the correlation heuristic.

Question	Condition comparaisons	$\chi 2$	*p*
1	CR-experimental (0.69) ~ CR-control (0.58)	1.196	0.27
	CH-experimental (0.36) < CH-control (0.90)	10.483	<0.00
2	CR-experimental (0.64) > CR-control (0.44)	3.629	<0.05
	CH-experimental (0.63) ~ CH-control (0.80)	1.522	0.22
3	CR-experimental (0.38) > CR-control (0.11)	8.663	<0.00
	CH-experimental (0.43) < CH-control (0.78)	8.502	<0.00
1 to 3 combined	CR-experimental (0.57) > CR-control (0.38)	10.042	<0.00
	CH-experimental (0.47) < CH-control (0.81)	18.336	<0.00

DISCUSSION & CONCLUSION

- Participants enrolled in the CMSS course performed better in solving the S-F problems than the participants who were not exposed to the CMSS course teachings.
- Similarly, participants enrolled in the CMSS course exhibited significantly less reliance on the correlation heuristic than the participants who were not enrolled in the CMSS course.
- The result supports prior research on the effectiveness of system-dynamics training and previous experiences in reducing S-F failures and reliance on the correlation heuristics (Kumar & Dutt, 2018; Sterman, 2010)
- In conclusion, the CMSS course may have facilitated a better understanding of S-F concepts. The better understanding of S-F concepts may have translated into significantly better problem-solving skills and a significant drop in reliance on correlation-heuristic.

FUTURE WORK

- Incorporate more S-F problems of varying difficulty levels and use the pre-post form of experimental design.
- Furthermore, collecting participant's responses at different time periods during the course and using questions of varying difficulty levels could help us discover which elements of the course are more effective in reducing the S-F failures.
- Cover a larger sample of the population to further enhance the results' generalizability.

ACKNOWLEDGEMENT

- We are grateful to the Indian Institute of Technology Mandi for providing the necessary resources for this experiment.

THANK YOU!

Contact: Gitanshu Choudhary
Email: nbgitanshu@gmail.com

References

- Cronin, M. A., Gonzalez, C., & Sterman, J. D. (2009). Why don't well-educated adults understand accumulation? A challenge to researchers, educators, and citizens. Organizational behavior and Human decision Processes, 108(1), 116-130.
- Dutt, V., & Gonzalez, C. (2012). Decisions from experience reduce misconceptions about climate change. Journal of Environmental Psychology, 32(1), 19-29.
- Gonzalez, C., Lerch, J. F., & Lebiere, C. (2003). Instance-based learning in dynamic decision making. Cognitive Science, 27(4), 591-635.
- Haskell, R. E. (2000). Transfer of learning: Cognition and instruction. Elsevier.
- Kumar, M., & Dutt, V. (2018). Experience in a climate microworld: Influence of surface and structure learning, problem difficulty, and decision aids in reducing stock-flow misconceptions. Frontiers in psychology, 9, 299.
- Sterman J. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin/McGraw-Hill: New York.
- Sterman, J. D. (2010). Does formal system dynamics training improve people's understanding of accumulation?. System Dynamics Review, 26(4), 316-334.
- Sterman, J., Fiddaman, T., Franck, T. R., Jones, A., McCauley, S., Rice, P., ... & Siegel, L. (2012). Climate interactive: the C-ROADS climate policy model.
- Sweeney, L. B., & Sterman, J. D. (2000). Bathtub dynamics: initial results of a systems thinking inventory. System Dynamics Review: The Journal of the System Dynamics Society, 16(4), 249-286.