The World is Flat: Modeling Educators' Misconduct with Cellular Automata

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Biography

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Misconduct in education is a serious problem internationally. As the education sector grows, so does the scale of misconduct. The large bureaucratic apparatus, overregulation, outdated and unclear rules, and poor audit create opportunities for abuse. The blending of public sector, private firms, and personal interests of educators and education bureaucrats leads to collusion and evolvement of different forms of misconduct, especially widespread in large university systems and school districts. Corruption and other forms of misconduct may be modeled in large educational organizations with strong vertical and horizontal ties with the help of cellular automata. This paper offers a theoretical framework and a methodology based on cellular automata to study corruption in large educational organizations, including school districts and state university systems. The presented methodology is based on cellular automata. In the essence of cellular automata are different programming characteristics designed to predict future misconduct. Starting with different cases or combinations of behavior on the workplace and working environment as initial conditions, the process of cellular automation simulates behavior of educators and results in images that depict likely future developments in educators' misconduct within educational and bureaucratic organizations. Applicability of the offered methodology and its value is in modeling, simulation, and control.

Key words: cellular automata, corruption, education, methodology, misconduct, modeling

Introduction

Misconduct in education is a serious problem internationally. As the education sector grows, so does the scale of misconduct. The large bureaucratic apparatus, overregulation, outdated and unclear rules, and poor audit create opportunities for abuse. The blending of public sector, private firms, and personal interests of educators and education bureaucrats leads to collusion and evolvement of different forms of misconduct, especially widespread in large university systems and school districts.

Educators' misconduct is not limited to embezzlement of the state funds by educational bureaucrats or collecting bribes from students by faculty members. Misconduct in education goes far beyond that and may be found in secondary and higher education sectors, in public and private sectors, in centralized and decentralized educational systems. It manifests itself in forms of bribery, embezzlement, extortion, fraud, nepotism, cronyism, favoritism, kickbacks, transgressing rules and regulations, bypass of criteria in selection and promotion, ghost teachers, cheating, plagiarism, research misconduct, data falsification, discrimination, and abuse of public property. In most of the instances corruption in education has a systemic character and hence can be modeled.

Cellular automaton offers a promising methodology to study misconduct in education. It allows making forecasts, assessments, and predictions on the scope and scale of corruption within organizations. Cellular automata, used in sciences, may be applied to investigate corruption in large hierarchical structures of educational organizations. This paper offers a theoretical framework and a methodology based on cellular automata to study corruption in large educational organizations, including school districts and state university systems.

The problem of misconduct in education

Misconduct in education includes misconduct that arises from university-business relations, academic misconduct, cheating, plagiarism, and other forms of fraud, misconduct in relations of professors and students including sexual misconduct, research misconduct, private tutoring that involves conflict of interest, bribery in admissions and grading, embezzlement of public funds and funds of private universities, abuse of public property, gross waste, and mismanagement of university property. All of these forms of misconduct were given consideration in numerous scholarly publications. Education misconduct can be found throughout the world, including developed nations, transition economies, and developing countries.

Major grounds for misconduct and corruption include the size of the system, amount of funds employed, intensity of monetary transactions, and complexity of the system. New York City, the largest school system in the country, has over 1.1 million students, a budget of over $14 billion, over 1,200 schools, and 140,000 employees. Los Angeles is the second largest, with three-quarters of a million pupils, a $7 billion budget, 900 schools, and 80,000 employees. Chicago, the third largest, has half a million students, a $3.5 billion budget, 600 schools, and 45,000 employees. The operating budgets of the New York City and Chicago districts are each larger than the entire amount most states invest in education. Corruption in education is significant and includes bribery, fraud, gross waste, embezzlement, nepotism, cronyism, favoritism, and other forms of misconduct (Segal, 2004).

Segal suggests estimating corruption, waste, and abuse on the basis of intensity by raising the following question: “Are they opportunistic and occasional or systemic and chronic?” (Segal, 2004) Referring to Ermann and Lundman (1978), Segal admits that some sporadic, opportunistic fraud and waste is almost inevitable in any large organization, while noting that systemic patterns suggest a deeper, constitutional problem: “What is striking about the New York City, Los Angeles, and pre-1997 Chicago school districts is how systemic and persistent corruption, waste, and abuse have been in certain non-core areas. The intensity of the problem is such that… investigators unearthed the same kinds of schemes year after year, sometimes for decades.” (Segal, 2004, p. 19) Corruption and lack of civic responsibility compromise the quality of schooling. Neither community involvement nor parental committees are helpful in restoring quality education. The literature on misconduct in education points to at least three important characteristics that are of interest for this study: the large size of educational systems and organizations where misconduct occurs, the systemic character of misconduct, and the role of peer pressure and oversight in preventing or perpetuating misconduct.

Literature review

Different theoretical frameworks are applied to study different forms of misconduct in large organizations. Lui (1986) considers dynamic models of corruption and inclusion of deterrence as a factor for reducing corruption or confining it within the certain limits. Carillo (2000, p. 3) points to possible collusion between supervisors and agents: “corruption can propagate within the hierarchy. We capture this recursive property of corruption by assuming that agents can share the bribe with their superiors in exchange for not being denounced.” The issue of collusion is addressed in Gong (2002), Khalil and Lawarree (1993, 1995, 1996), Laffont and Martimort (1997), Lambert-Mogiliansky (1995), Olsen and Torsvik (1998), Strausz (1996), and Tirole (1986). These works examine collusion-proof contracts in different settings of the principal-agent frame.

Principal-agent theory, first developed in economics to study relations between the owners of the enterprises and their managers, is used to investigate corruption. The principal-agent problem in the fields of public policy and economics is described by Banfield (1975), Becker and Stigler (1974), Darden (2002), Kunicova and Rose-Ackerman (2001), Rose-Ackerman (1975, 1978, 1999), and Solnick (1998). Principals and agents are both self-interested actors, so their preferences often diverge. This agency problem not only urges a principal to monitor the agent, but also to try different mechanisms of controlling the agent's behavior. Referring to Klitgaard (1988, p. 23), Gong states that corruption "occurs when an agent betrays the principal's interests in pursuit of his/her own or when the client corrupts the agent if he or she (client) perceives that the likely net benefits from doing so outweigh the likely net costs." (Gong, 2003, p. 88) Describing collective corruption, Gong says that its purpose is "to maximize individual gains and/or minimize the risks associated with corrupt activities." (Gong, 2003, p. 88)

Shleifer and Vishny (1993), and Ahlin (2001) investigate possible implications of centralization and decentralization of corrupt organizations on the total volume of corruption. Shleifer and Vishny (1993) consider vertical structures and conclude that decentralization of corruption leads to an increase in the total volume of graft collected by corrupt bureaucrats. Ahlin (2001) comes to the similar conclusion in his research on horizontal structures and regional distribution of corruption and. Corruption in hierarchies is researched by Bac (1996, 1998, 2001), Olsen and Torsvik (1998), and Varian (1990) in connection with the principal-agent theory. Olsen and Torsvik (1998) consider collusion in organizations within the principal-agent frame. Guriev (2001) investigates three-tier hierarchies with principal, bureaucrat, and agents. Carillo (2000) develops a four-tier hierarchical model that includes corrupt behavior. Waite and

Allen (2003) follow the possible top-down and bottom-up channels of conveying benefits of corruption as well as resources in educational systems.

Cost-benefit analysis is used in designing cost-effective models and mechanisms of supervision. Bac (1998) investigates the problem of organizing three agents in a hierarchical monitoring structure and designing a corresponding incentive system to minimize the cost of implementing a target level of corruption. Bac (1996, 1998) combines hierarchies, cost-benefit analysis, and collusion in potentially corrupt structures and demonstrates that the possibility of collusion may prevent the implementation of anything less than full corruption. He asserts, “In relatively flat hierarchies, economies of scale in monitoring reduce implementation costs but may increase the risk of collusion.” (Bac, 1998, p. 110) Different types of hierarchies include the hierarchy where one supervisor monitors two subordinates within the supervision chain, which is shown to display in its upper part a higher risk of collusion than in its lower part. Different hierarchical structures are then contrasted with each other in order to follow the performance of each in terms of better supervision and control. Lately, methodologies normally used in sciences find their way in research of corruption, including primarily its economic aspects (Shao et al., 2007; Blanchard et al., 2005).

Theoretical framework

As denoted by Wirl (1998, p. 203) based on works of Wolfram (1986, 1994), a cellular automaton is an iterating map *F* that updates at each period *t* the value or action of a site *i*, denoted *a(t)*, depending on the neighbors actions in period *(t-1)* from a fixed radius *r* into the set of possible states, which is discrete and of dimension *k*, {0,1,2,…,k-1}:

$$a_i(t) = F(a_{i-r}(t-1), a_{i-r+1}(t-1), \ldots, a_{i+r}(t-1)).$$

In deterministic cellular automata, the new state of a cell is determined on the basis of its actual state and states present in the neighboring cells. In the simplest case, a one-dimensional cellular automaton anticipates two possible states and a neighborhood of three cells. With two possible states and the neighborhood of three there are eight possible combinations of initial conditions and outcomes for the cell in focus. In a two-dimensional cellular automaton, cells can be positioned in hexagonal or square configurations. In a Von Neuman neighborhood, cells are influenced by their neighbors from four sides, while in a Moore neighborhood diagonal links are also involved. Hence, a Von Neuman neighborhood consists of five cells, including the cell in focus, and a Moore neighborhood consists of nine cells. Stochastic or three-dimensional cellular automata are more complex forms than one- and two-dimensional models. In stochastic models, the transition rule allows for stochastic or probabilistic distribution. In such case the model can indicate the next state of the cell in focus based on the probability of its changing its initial state or preserving it. Stochastic cellular automaton reflects on spatial inter-specific competition of neighboring cells for the determination of the focus' cell next stage.

Ideally, any large bureaucracy or professional organization, including those with complex hierarchical structures, can be decomposed to a simple linear one-period system. The resulting abstraction can be processed with cellular automata based on the set rules of functions. In some instances initial randomly distributed cells of types *a* and *b* can evolve into a homogenous state at a certain stage. In other cases, evolution will lead to a set of infinite separated simple stable or periodic structures depicting different combinations of cells *a* and *b*. As applied to employees' behavior in complex organizations, the initial chaotic patterns of behavior can transform into periodic patterns, homogenous state, or chaotic unorganized patterns indistinguishable from the initial patterns. Periodic patterns reflect repetitive behavior of employees. Evolution leads to emergence of complex localized structures. In this case, some very complex spatial patterns may arise and reproduce over long periods of time. Such patterns may also exhibit intriguing spatial propagation despite a perfect conservation of their shape. Thus, surprisingly complex behaviors can arise from the action of randomly distributed cells with distinct patterns of behavior and result in locally concentrated processes that are not strategically directed but rather sporadic.

Methodology

In the simplest case, a cellular automaton consists of a line of cells or, as in our case, education bureaucrats, with each cell carrying a value of zero or one. The site values evolve synchronously in discrete time steps according to the values of their nearest neighbors to indicate the effect of peer pressure and moral constraints. The analysis involves initial determination of educators who do and do not commit misconduct. The next step is to determine the period, or the single step, along the timeline. For instance, for educational financiers the period might be one financial year, while for teachers it might be one week or one academic year. The third step involves programming, or setting the rules according to which cellular automation is to progress. The rules include determinants of peer pressure and anticipated economic benefits from corruption. Further developments of the given methodology are in the two-dimensional cellular automata that can produce patterns with complicated boundaries (Packard and Wolfram, 1985). Cellular automata are based on iterated functions. The process of iteration, i.e. a repetitive process, allows for an infinite number of equal steps.

Model

This paper offers the following theoretical model for application of cellular automata to misconduct in education sector and more specifically to corrupt educators. It considers educators as rational actors that calculate their expected cost and benefit of being involved in misconduct and make decisions about whether to participate in corrupt activities based on net benefits. It is assumed that net benefit from accepting a bribe or committing other possible forms of misconduct is a function of the benefits of corruption, including the size of a bribe or , the risk of being exposed and prosecuted, and the social pressure from colleagues as well as personal ethics, $Q = f(E,C,S)$.

Models of corruption presented in economic and political science literature normally do not account for social environment and personal characteristics of educators. Specifically, rationalistic approaches to corruption formalized in such models do not give consideration to such factors as influence of the educator's colleagues, their interactions, and moral and ethical beliefs of the educator. The environment in which corruption is to take place as well as the educator's personal views on corruption will be denoted as social pressure. The task is to operationalize social pressure and include it in the consideration of corrupt behavior and decision-making regarding the support of the system. We will incorporate social pressure into the initial model of corruption and compliance with the formal and informal rules that exist in the system and simulate the educator's behavior with the help of numerical examples.

Social pressure includes peer pressure on the educator and his moral considerations. It is assumed that in corrupt organizations peer pressure works toward encouraging corruption. Higher peer pressure results in a higher probability for the educator to accept bribes and to comply with the current system. His moral considerations, however, can work in the opposite direction. Contrary to peer pressure, the educator's morality negatively impacts his willingness to accept bribes. Net social pressure is calculated by subtracting the numerical value of moral considerations from the numerical value of peer pressure. The model of decision-making based on the net benefits the educator *i* would expect from corruption is presented in the equation below:

$$Q_{i,t-1} = E_{i,t-1} + (p_{i,t-1} - m_{i,t-1}) - (d_{t-1} \times r_{t-1}), \qquad (1)$$

where *i* denotes the educator, *E* is the economic benefit from being involved in corruption, *d* is the degree of punishment defined by law for a corrupt educator, *r* is the probability of being exposed, *C* is the total cost of being corrupt, *p* is the peer pressure, *m* is the moral considerations, *S* is the net social pressure, *Q* is the net benefit from corruption. All variables are taken in the period *t*-1. If $Q<0$, then the educator will decide not to support the current system. If $Q>0$, then the educator will decide to support the current system.

Opportunity costs of working in the education sector for period *t*-1 can be equal to the educator's present salary, benefits of corruption, social pressure, and risks, associated with bribery and other forms of corruption. In this case the educator is neutral to the existing system. He/she neither supports the system, nor is he/she willing to change it because his/her position in terms of income and personal wealth will likely stay unchanged. The equality can be presented as follows:

$$O_{i,t-1} = L_{i,t-1} + E_{i,t-1} + (p_{i,t-1} - m_{i,t-1}) - (d_{t-1} \times r_{t-1}) \qquad (2)$$

If $O<0$, then the educator will decide not to support the current system. If $O>0$, then the educator will decide to support the system. Peer pressure is understood as a pressure of corrupt colleagues on the educator toward corruption. Such a pressure may come from other educators within the department and the administration. Accordingly, the value of p is anticipated to always be positive. The state pressure on corrupt educators is exogenous and hence is not included in the initial model. The educator's moral standards are assumed to be against corruption, and hence m is negative. A numerical example of defining the educator's decision of whether to support the system in exchange for the opportunities to collect bribes or commit misconduct without being punished is presented in Table 1.

Model simulation

Table 1 provides a numerical example for the extended model presented above (2) for the period t-1. The assumption is made that social pressure depends on two educators who are the nearest colleagues of the educator whose decision is at stake. The educator's colleagues are denoted in the table as i-1 and i+1. Let us assume that the social pressure function takes the values 0 for deviating from the colleagues' behavior, 1 for conforming to one of the two colleagues, and 2 for a uniform corrupt behavior of all three educators. The values are obtained as results from the combination of peer pressure and moral considerations. Peer pressure is equal to 2 if both of the educator's colleagues are corrupt, 1 if only one of colleagues is corrupt, and 0 if both of colleagues do not accept bribes. Moral considerations are assigned values of 0 or 1, depending on whether the educator already accepts bribes.

The degree of punishment for corrupt behavior is uniform for all of the possible combinations of corrupt and uncorrupt educators and has a value of 4. The probability of being exposed depends on the corruptness of the colleagues-educators. If the educator is not corrupt, the probability of being exposed is equal to 0 only if both of his colleagues are corrupt. However, if the educator will accept a bribe while having both of his colleagues not involved in corrupt activities, the probability of being exposed is equal to 1. Having only one of two colleagues corrupt makes the probability of being exposed equal to 0.5. Accordingly, the value of the total cost of being corrupt varies from 0 to 2. The value of present or legal salary of the educator *i* is constant for all three periods, *t*-1, *t*, and *t*+1, uniform, and equal to 2. The fair market salary or the opportunity costs of the educator *i* is also constant for all the three periods, *t*-1, *t*, and *t*+1, uniform, and equal to 3.

The value of the economic benefits from corruption is equal to 2. It is uniform for all the possible combinations. It is assumed that bribes are collected over a certain period of time. This period of time is similar to the one over which the corrupt educator bears the risk of being exposed and prosecuted. As can bee seen from the numerical example, the degree of punishment is twice as high as the expected benefits from corruption. This encourages corrupt educators to seek safe harbors, such as highly corrupt environments. A good example of a safe harbor would be a department where most or all of the educators are corrupt.

Let us now assume that the authorities have lowered the degree of punishment that a corrupt educator may face if accused of corruption and prosecuted. We lower the existing level of punishment of 4 down to 2. A numerical example of defining the educator’s decision of whether to support the existing system in exchange for the opportunities to collect benefits of corruption without being punished is presented in Table 3.

Table 1

A numerical example of defining the educational employee's decision of whether to support the system, based on such considerations, as total benefit, costs, and social pressure, (period *t*-1)

Education employee			Economic benefits from corruption, *E*	Costs of corruption, risk			Social pressure			Net benefits, *Q*	Present legal salary, *L*	Opportunity costs, *O*	Decision (whether to support the existing system), *D*
i-1	*i*	*i+1*		Degree of punishment, d	Probability of being exposed, *r*	Total costs, *C*	Peer pressure, *p*	Moral considerations, *m*	Net social pressure, *S*				
yes	yes	yes	2	4	0	0	2	0	2	4	2	3	Yes
yes	yes	no	2	4	0.5	2	1	0	1	1	2	3	No
yes	no	yes	2	4	0	0	2	1	1	3	2	3	Yes
yes	no	no	2	4	0.5	2	1	1	0	0	2	3	No
no	yes	yes	2	4	0.5	2	1	0	1	1	2	3	No*
no	yes	no	2	4	1	4	0	0	0	-2	2	3	No
no	no	yes	2	4	0.5	2	1	1	0	0	2	3	No
no	no	no	2	4	1	4	0	1	-1	-3	2	3	No

* In one case in the numerical example the opportunity costs of the educator *i* are equal to the sum of his present salary, benefits derived from corruption, and risks that arise due to being involved in corrupt activities. Ideally, this would mean that the education employee who faces the choice of either supporting the current system or otherwise, is indifferent or neutral. The moral values are already given consideration in the example. However, as far as the educator's decision is concerned, it is marked as "No," meaning that the educator will likely decide not to support the system. This can be explained by some other external factors that are likely not to be in favor of supporting the system that allows corruption. Let us also explain it by some minimal transaction costs that might be incurred by the educator in order to accept bribes, embezzle, and extracts other benefits from corruption.

Table 2

A numerical example of defining the educational employee's decision of whether to support the system, based on such considerations, as total benefit, costs, and social pressure, (period *t*)

Education employee			Economic benefits from corruption, *E*	Costs of corruption, risk			Social pressure			Net benefits, *Q*	Present legal salary, *L*	Opportunity costs, *O*	Decision (whether to support the existing system), *D*
i-1	*i*	*i+1*		Degree of punishment, d	Probability of being exposed, *r*	Total costs, *C*	Peer pressure, *p*	Moral considerations, *m*	Net social pressure, *S*				
yes	yes	yes	2	2	0	0	2	0	2	4	2	3	Yes
yes	yes	no	2	2	0.5	1	1	0	1	2	2	3	Yes
yes	no	yes	2	2	0	0	2	1	1	3	2	3	Yes
yes	no	no	2	2	0.5	1	1	1	0	1	2	3	No*
no	yes	yes	2	2	0.5	1	1	0	1	2	2	3	Yes
no	yes	no	2	2	1	2	0	0	0	0	2	3	No
no	no	yes	2	2	0.5	1	1	1	0	1	2	3	No
no	no	no	2	2	1	2	0	1	-1	-1	2	3	No

*Similar to the period *t*-1, in one case in the numerical example in the period *t* the opportunity costs of the educator *i* are equal to the sum of his present salary, benefits derived from corruption, and risks that arise due to being involved in corrupt activities. Accordingly, as we did in Table 1, we assume that the educator is in opposition to the existing system.

Table 3

A numerical example of defining the educational employee's decision of whether to support the system, based on such considerations, as total benefit, costs, and social pressure, (period *t*+1)

Education employee			Economic benefits from corruption, *E*	Costs of corruption, risk			Social pressure			Net benefits, *Q*	Present legal salary, *L*	Opportunity costs, *O*	Decision (whether to support the existing system), *D*
i-1	*i*	*i+1*		Degree of punishment, d	Probability of being exposed, *r*	Total costs, *C*	Peer pressure, *p*	Moral considerations, *m*	Net social pressure, *S*				
yes	yes	yes	2	1	0	0	2	0	2	4	2	3	Yes
yes	yes	no	2	1	0.5	0.5	1	0	1	2.5	2	3	Yes
yes	no	yes	2	1	0	0	2	1	1	3	2	3	Yes
yes	no	no	2	1	0.5	0.5	1	1	0	1.5	2	3	Yes
no	yes	yes	2	1	0.5	0.5	1	0	1	2.5	2	3	Yes
no	yes	no	2	1	1	2	0	0	0	1	2	3	No*
no	no	yes	2	1	0.5	0.5	1	1	0	1.5	2	3	Yes
no	no	no	2	1	1	2	0	1	-1	0	2	3	No

*Similar to periods *t*-1 and *t*, in one case in the numerical example in the period *t*+1 the opportunity costs of the educator *i* are equal to the sum of his present salary, benefits derived from corruption, and risks that arise due to being involved in corrupt activities. Accordingly, as we did in Tables 1 and 2, we assume that the educator is in opposition to the existing system.

As can be seen from Table 3, the number of cases when the educator will choose to comply with the system increased 100 percentage points, from 2 to 4. Hence, a voluntary reduction of the degree of punishment from 4 in period *t*-1 down to 2 in period *t* leads to a significant increase in the number of cases in which the educator will support the system.

Despite the significant increase in the number of cases when the educator will support the existing system in period *t*, it constitutes only half of all possible cases. This is not sufficient for the system that wants to sustain itself. The system can not afford an increase in the salaries it pays to college professors due to budget constraints. Nor can it facilitate an increase in the total sum of benefits educators generate from corruption. The size of bribes and the total scale and scope of bribery and other forms of corruption in education, as well as in other sectors of the economy, are mostly determined by the market forces, including consumer demand and clientele base, not by the state.

Further proliferation of the corruption and compliance policy is needed. Therefore, as follows from equations (1) and (2), the authorities are interested in the reduction of the total cost of being involved in corruption for each educator. This can be done easily since the punishment mechanism is administered by the state. While the state can not regulate the risk of exposure *r*, it can regulate the degree of punishment *d*. The degree of punishment consists of the probability of being prosecuted and sentenced and the level of punishment chosen by the state in regard to the corrupt educator. While formally the degree of punishment may be high, the actual degree of punishment *d* may be relatively low, based on the low rate of prosecution. Furthermore, prosecution itself is a threat only for those who choose not to comply with the authorities' demands.

Let us assume that the authorities have lowered the degree of punishment that a corrupt educator may face if accused of corruption and prosecuted. We reduce the existing level of punishment of 2 in period *t* down to 1 in period *t*+1. A numerical example of defining the educator's decision of whether to support the system in exchange for the opportunities to collect bribes without being punished is presented in Table 3. The number of cases when the educator will chose to comply with the system's demands increased 50 percentage points, from 4 to 6. Hence, a further voluntary reduction of the degree of punishment from 2 in period *t*-1 down to 1 lead to a significant increase in the number of cases in which the educator will opt for supporting the system. Probability of being exposed may be a function of peer pressure. Accordingly, an increase in peer pressure may lead to a decrease in the probability of being exposed and, hence, to a further decrease in the total cost of being involved in corrupt activities. This will lead to an even higher probability of the educator being in support of the existing system.

Results

The results of cellular automation simulation, including those obtained after analyzing the large educational organizations, are best seen as graphic depictions. They might be simple yet reliable assessments of the future developments that reflect the scale and the scope of educational misconduct. Wirl says that "Although cellular automata are very simple, deterministic machines and thus crude approximations of real, economic situations, they are capable of describing self organization and complex patterns (of corruption)." (Wirl, 1998, p.199) The images, both black and white and in color, depending upon the initial characteristics of the cells and the authors' determination, allow for visual examination of future patterns of misconduct. The structures with the clear aisles or sporadic distribution of corrupt educators point toward particular educators who are likely to commit misconduct in the future. Most interestingly, the predictions point to those members of large organizations who are most likely to be involved in misconduct after a certain period of time and yet who at the present may even be unaware of this.

We present three simulations based on distinct functions of deterministic patterns of behavior. The images appear structuralistic in nature, with dispersed triangles of different sizes, often localized in groups, with diffused and randomly distributed single cells. In all of the images generated below, black color identifies a corrupt educator, while white color identifies a non-corrupt educator. Two neighbors, one on the left and one on the right, influence their neighbor in the middle. We focus on the educator in the middle. For each function, we use 1000 educators in a one-year, i.e. 365-day period, where each cell represents a given educator in a given day.

We present three functions. Each of the functions reflects a certain balance of powers and combination of factors, including central authorities, educators, pay rates, risk of exposure, degree of punishment, and peer pressure. Based on the significance of these initial factors in each of the three cases, we formulate certain dependencies expressed as functions 1, 2, and 3.

Function 1. (Rule 18). Let us assume that: 1. three corrupt educators grouped together cause the authorities to initiate an investigation; accordingly, the risk of punishment for being involved in misconduct increases, and as a result the educator refuses to participate in corruption. Hence, having two corrupt neighbors in period t-1 causes the educator to become non-corrupt in period t; 2. having one non-corrupt neighbor causes the corrupt educator to become non-corrupt in period t, if he was corrupt in period t-1; 3. having two corrupt educators-neighbors causes the educator to remain non-corrupt in period t, because he/she reasonably expects that his/her neighbors will remain corrupt in period t and that three corrupt educators will cause the authorities to initiate an investigation. The risk will go up and the educator will have to refuse corruption; 4. having two non-corrupt neighbors causes the corrupt educator to become non-corrupt, since peer pressure in this case pushes him/her toward non-corruption. In addition, the risk of being exposed by non-corrupt peers is higher; 5. finally, having two non-corrupt neighbors in period *t*-1 causes the non-corrupt educator to remain non-corrupt in period *t*. The results of cellular automaton for the function 2 are presented in figures 1 through 4.

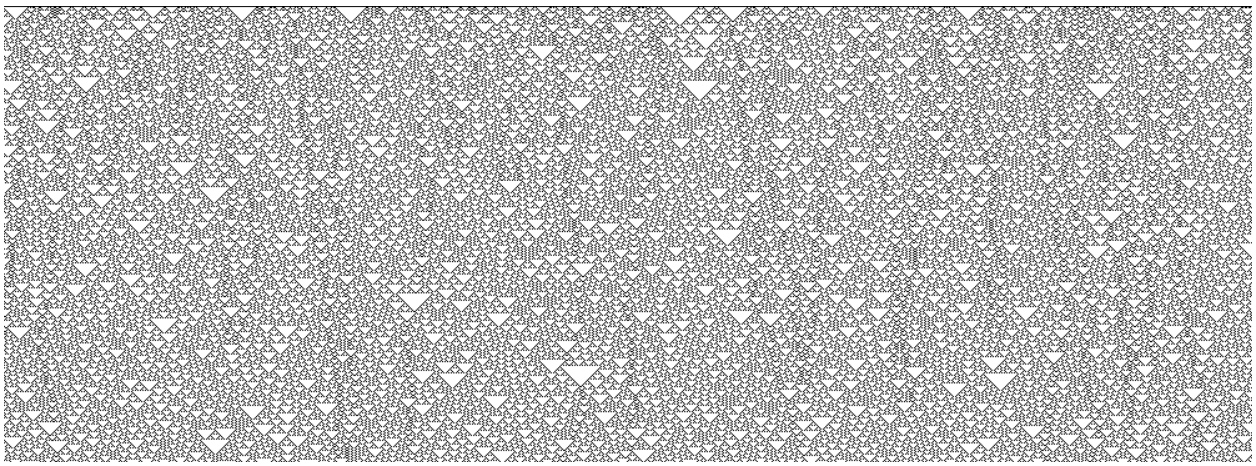

Figure 1. Function 1. Cellular automaton for 1000 educators in a 365-day period, with corrupt educators being distributed randomly in day one

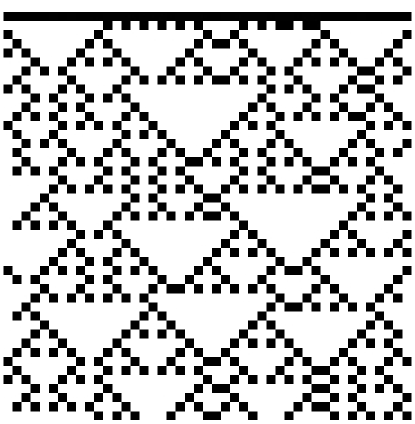

Figure 2. Function 1. Randomly selected magnified textural structure

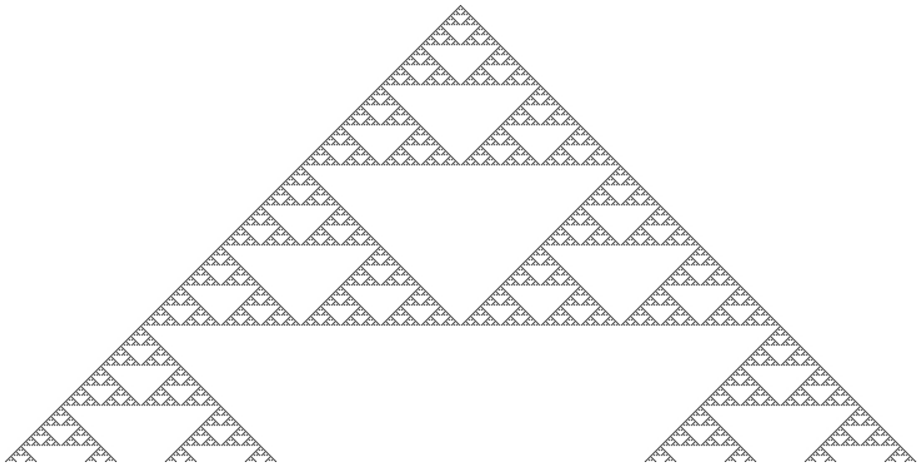

Figure 3. Function 1. Cellular automaton for 1000 educators in a 365-day period, with one corrupt educator initially in day one

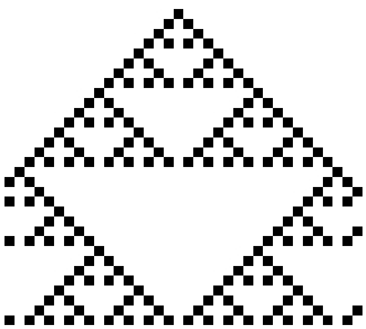

Figure 4. Function 1. Randomly selected magnified textural structure

Function 2. (Rule 126). Let us assume that: 1. three corrupt educators grouped together cause the authorities to initiate an investigation; accordingly, the risk of punishment for being involved in misconduct increases, and as a result the educator refuses to participate in corruption. Hence, having two corrupt neighbors in period *t*-1 causes the educator to become non-corrupt in period *t*; 2. having one corrupt neighbor allows the corrupt educator to remain corrupt in period *t*, if he was corrupt in period *t*-1; 3. having one corrupt neighbor in period *t*-1 encourages the non-corrupt educator to become corrupt in period *t*; 4. having two corrupt educators-neighbors in period *t*-1 allows non-corrupt educator to become corrupt in period *t*; 5. having two non-corrupt neighbors allows the corrupt educator to remain corrupt, since peer pressure in this case is weaker and does not push him/her toward non-corruption. In addition, the risk of being exposed by non-corrupt peers is lower. 6. finally, having two non-corrupt neighbors in period *t*-1 causes the non-corrupt educator to remain non-corrupt in period *t*. The results of cellular automaton for the function 2 are presented in figures 5 through 8.

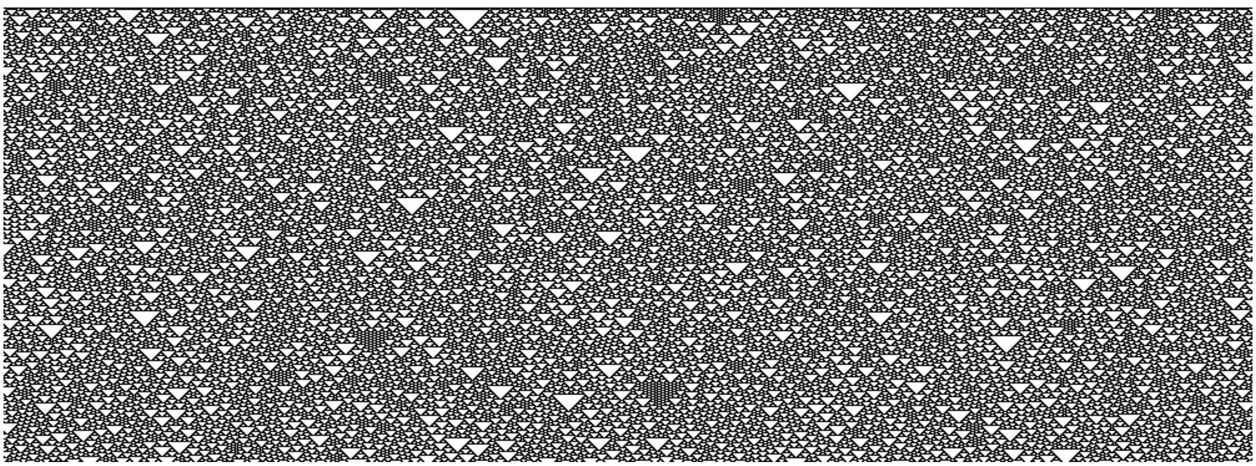

Figure 5. Function 2. Cellular automaton for 1000 educators in a 365-day period, with corrupt educators being distributed randomly in day one

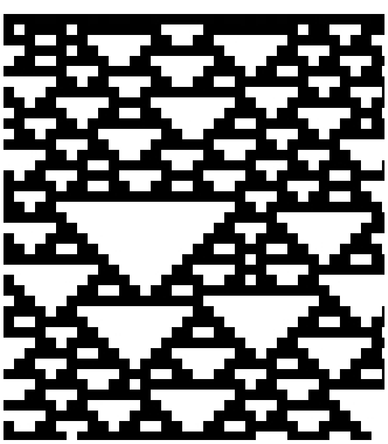

Figure 6. Function 2. Randomly selected magnified textural structure

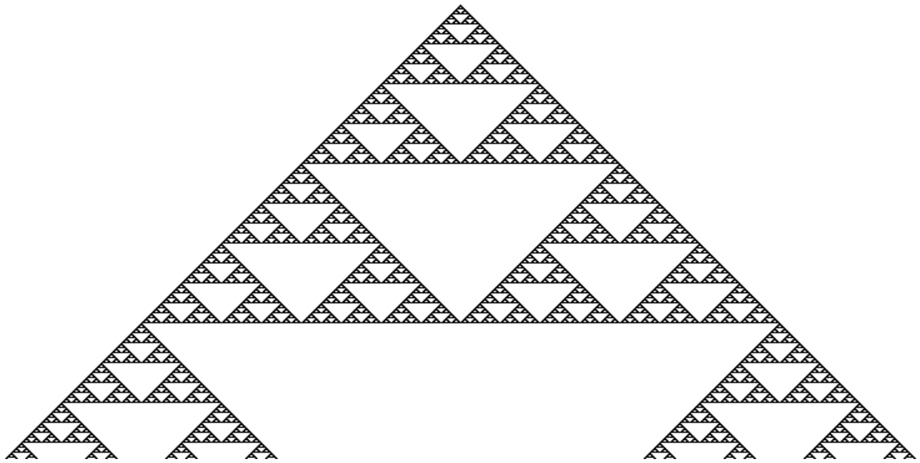

Figure 7. Function 1. Cellular automaton for 1000 educators in a 365-day period, with one corrupt educator initially in day one

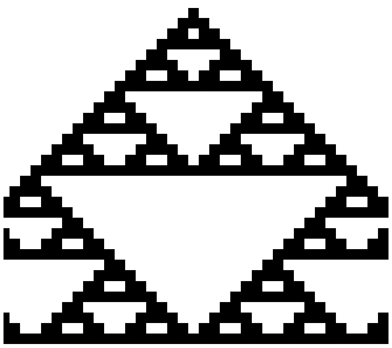

Figure 8. Function 2. Randomly selected magnified textural structure

Function 3. (Rule 86). Let us assume that: 1. three corrupt educators grouped together cause the authorities to initiate an investigation; accordingly, the risk of punishment for being involved in misconduct increases, and as a result the educator refuses to participate in corruption. Hence, having two corrupt neighbors in period *t*-1 causes the educator to become non-corrupt in period *t*; 2. having one corrupt neighbor causes the corrupt educator to remain corrupt in period *t*; 3. having one corrupt neighbor causes the non-corrupt educator to become corrupt in period *t*; 4.

having two corrupt educators-neighbors in period *t*-1 causes the educator to remain non-corrupt in period *t*, because he/she reasonably expects that his/her neighbors will remain corrupt in period *t* and that three corrupt educators will cause the authorities to initiate an investigation; 5. having two non-corrupt neighbors allows the corrupt educator to remain corrupt, since peer pressure in this case is weak and does not push him/her to become non-corrupt; 6. finally, having two non-corrupt neighbors in period *t*-1 causes the non-corrupt educator to remain non-corrupt in period *t*. The results of cellular automaton for the function 3 are presented in figures 9 through 12.

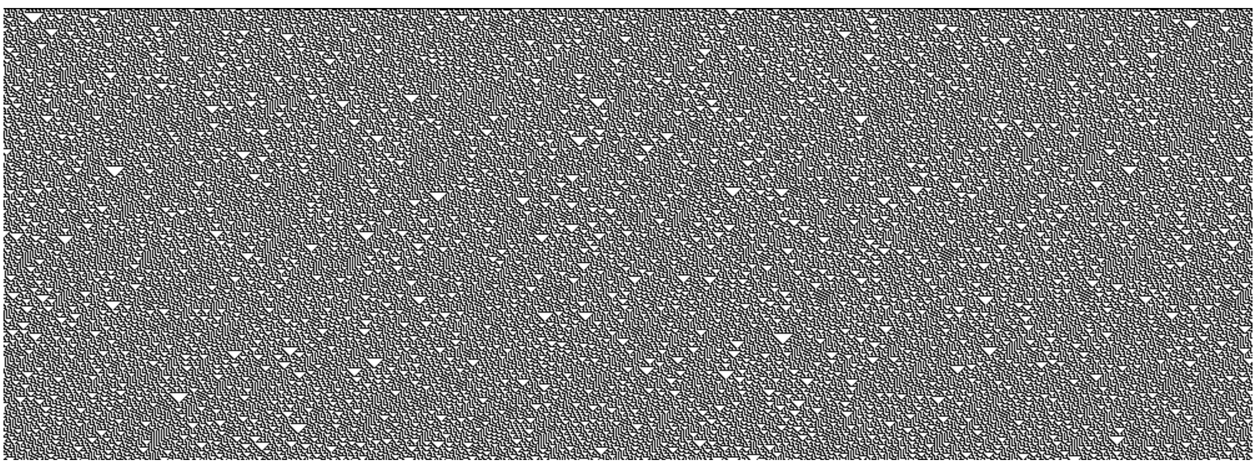

Figure 9. Function 3. Cellular automaton for 1000 educators in a 365-day period, with corrupt educators being distributed randomly in day one

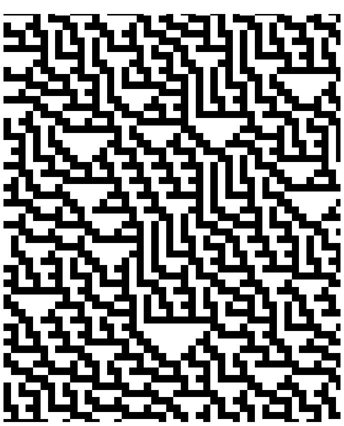

Figure 10. Function 3. Randomly selected magnified textural structure

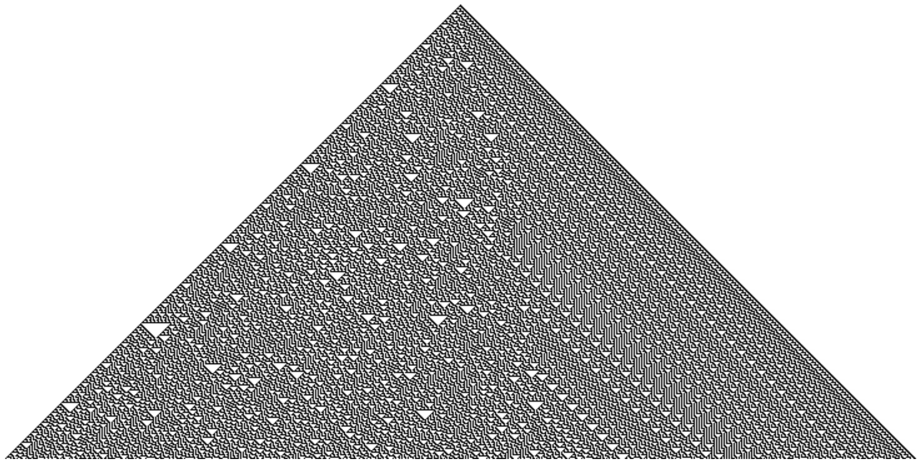

Figure 11. Function 3. Cellular automaton for 1000 educators in a 365-day period, with one corrupt educator initially in day one

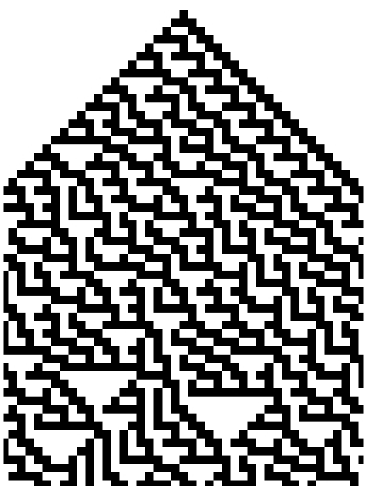

Figure 12. Function 3. Randomly selected magnified textural structure

Functions 1, 2, and 3, depicted on the images, do not necessarily correspond with the numerical examples we offered earlier. But in the essence, lesser peer pressure to be non-corrupt and the risks associated with participation in corrupt activities become definitive in educators' behavior in both numerical simulations and graphic representations. According to Function 1, the educator is unlikely to be encouraged to participate in misconduct in most of the instances. As a result, the structure of the cellular automaton for 1000 educators in a 365-day period, with corrupt educators being distributed randomly in day one and with one corrupt educator initially in day one, depicted in figures 1 and 3, respectively, is of a lesser density than that of Function 2. Cellular automaton based on Function 2 appears to have somewhat similar structure, but is clearly denser. This means that higher peer pressure to become corrupt and lesser risk of prosecution make the number of instances of having corrupt educators is much higher.

Finally, as depicted in figure 9, cellular automaton based on Function 3 is less chaotic and has a more structured appearance, than do cellular automata based on Functions 1 and 2. Figure 11 presents a quite astonishing pattern of distribution of educators' misconduct that starts from a single corrupt educator in day 1 and by the end of the year there are already a few hundred corrupt educators with a perspective of further proliferation until the margins are reached. The triangle that reflects the area of misconduct spread in the educational organization has a much higher density than the pyramidal structures in figures 3 and 7. Equally interesting is that there is a clearly visible asymmetry in the way the cellular automaton progression is structured. The right side of the triangle and its center is structured along horizontal and vertical lines, while the left side of the equation is grouped more along the diagonal lines directed from the center parallel to the left lateral position.

Concluding remarks

The presence of corruption in the education sector throughout the world is obvious; it is presented in scholarly work and is proven based on legal cases, surveys, interviews, and numerous publications in the media. Corruption in many national education systems has a systemic character, is endemic to the society, and often reaches epidemic proportions. Access to education, academic grades, term papers, degrees, credentials, and honors are all for sale.

Educators of all ranks in many countries are grossly underpaid along with other public employees. They abuse their position in order to sustain themselves. Chronic underfunding, poor coordination, lack of transparency and control result in an education system riddled with all types of misconduct, from outright bribery and kickbacks to cronyism and ghost teachers, and from grand scale embezzlement and fraud to gross waste and petty theft.

This paper presents cellular automation, a relatively new methodology to study misconduct in large educational organizations, and uses simulation to model the behavior of educators, including factors that influence their decision making. This methodology may be used beneficially for future research in organizations and corrupt hierarchies, including school districts and higher education institutions and make valid and credible forecasts.

Cellular automaton may prove to be a more effective and cost-efficient methodology than estimation of systems of partial differential equations. Research of corruption with the use of cellular automata is virtually nonexistent. Wirl (1998) presents basic socio-economic typologies of bureaucratic corruption and their implications as studied through the application of cellular automata. Computational organization theory is presented in works of Carley and Prietula (1994), Carley and Gasser (1999), as well as in the journal of *Computational & Mathematical Organization Theory*. Some of the aspects of organizational corrupt structures may be studied along the lines of computational organization theory which uses computational and mathematical methods to study organizations, formulates models, and develops tools and procedures to validate organizational models. Eventually, this methodology will be used to improve educational organizations through an increase in their organizational effectiveness and efficiency and a reduction and future prevention of misconduct.

Cellular automaton is not universal, as any other methodology. Nevertheless, cellular automaton based simulations can be used to model a wide variety of different environments and patterns of development, from corrupt practices among faculty in Tbilisi State University in the country of Georgia to education policy adoption strategies of states in the US, and from distinct modes of research misconduct in large research universities and think tanks to opportunistic behavior of education bureaucrats and school teachers in large public school districts.

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