

Northeast Journal of Complex Systems (NEJCS)

Volume 1

Number 1 *Inaugural and Special Issue: CCS 2018*

Satellite Symposium on Complex Systems in Education

Proceedings

Article 3

September 2019

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Recommended Citation

Tsiouplis, Eugenia and Stamovlasis, Dimitrios (2019) "Rethinking Educational Reforms Through a Complex Dynamical Systems Approach: Preliminary Report from an Empirical Research," *Northeast Journal of Complex Systems (NEJCS)*: Vol. 1 : No. 1 , Article 3.
DOI: [10.22191/nejcs/vol1/iss1/3](https://doi.org/10.22191/nejcs/vol1/iss1/3)

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Rethinking Educational Reforms Through a Complex Dynamical Systems Approach: Preliminary Report from an Empirical Research

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Abstract

Literature on educational reforms is rich of cases where changes have been attempted, without however to attain success. Likewise the Greek education system had experienced a lot of reforms, most of which have failed to make the intended changes and they attenuated shortly after their implementation or they ceased at the stage of legislative planning. On the other hand, the traditional research have failed to develop a coherent theoretical perspective and provide satisfactory interpretations of the perpetually unsuccessful reforms. This paper is part of wider project which attempts to address the above issue following the Complex Dynamical Systems (CDS) perspective, that is, by fostering the CDS epistemological assumptions and applying nonlinear methodological approaches. This endeavor focuses on teachers' readiness for change and explores the dimensions of the resistance to change related to the values, attitudes, dysfunction beliefs and planed behaviors of teachers. Given that the project is still ongoing, here, only the outline of the research design and the strategy followed are discussed along with some preliminary findings. At a first stage, the investigation implemented focus-group settings to reveal clues of those dimensions. The recorded data were analyzed via orbital decomposition analysis (ODA), a method designed for categorical time series and discourse analysis. Some of the crucial dimensions of resistance-to-change were subsequently measured via a survey instrument and were used to predict teachers' position with linear and nonlinear models. Statistical analysis showed that the cusp catastrophe model was superior to the linear alternatives and revealed discontinuities in teachers' positions, while certain variables proved to be bifurcation factors. The implications of these findings are discussed, while methodological aspects of ODA and catastrophe theory modeling are briefly presented. The present work sets a framework for the application of complexity theory and nonlinear dynamics in organizational theory of educational change.

Keywords: complexity theory, educational policy, resistance to change evaluation, focus group

1. Introduction

1.1 Educational reforms

Literature on educational reforms is rich of cases where changes have been attempted at all levels of the education system (e.g. Holmes, Clement & Albright, 2013; Terhart, 2013; Van Veen & Slegers, 2006), while most of them have not been finalized. The percentages of failures in organizational changes are estimated to be 80-90% (Cope, 2003) and this sparks a special interest to organizational researchers, because those attempts had a negative long-term impact (both financial and moral) on the whole educational process (Gilley, Gilley & McMillan, 2009). Some scholars, however, expressed an optimistic view that we have learned from those failed reforms, and stressed the need to reconsider the concept of change (Hughes, 2011). It has also been noted that in most cases, these reforms have been attempted without ensuring the consensus of active teachers, while there were no supportive mechanisms for the desired changes (Elmore & City, 2007; Trombly, 2014). Often, as soon as the ensuing failure was noticed, the reform measures were reintroduced under different names and designations (Goh, Cousins & Elliott, 2006), actions which, likewise, were not effective. The above general remarks hold also for the Greek Education, which since 1982, went through multiple reforming attempts focusing on the evaluation systems of the educational work and the school units. The present paper focuses on failed education reforms and reconsider theoretical and practical issues.

The challenge posed to scholars investigating the reform failures in educational systems is the interpretation of those failures. Relevant analyses have pointed out several facets as causative features. For example, the reform implementation was merely decision and action of the policymakers, bureaucrats who had no idea about the everyday school and classroom processes, while teachers' positions were ignored (Moran, 2015). This makes the resisting attitudes understandable, which are fostered by the major part of the teachers' community. Investigating those attitudes Hargreaves (2005) found that they depend of a number of factors and individual difference, such as, age, career stage, professional identity and degree of engagement. For instance younger teachers, at the beginning of their career, are likely to be enthusiastic, optimistic and more ready to adapt the reforms. On the contrary, elder teachers, at the end of their career, are more likely to feel tension, fatigue or exhaustion, so they can hardly conform to any new situation, and thus the degree of resistance to change might be greater (Goodson, Moore & Hargreaves, 2006). It is noteworthy that the cases or situations where a reform had no disputable reception were in those schools with cooperative climate between school principal and teachers (Siu, 2008).

In general, policymakers in education follow a top-down approach in managing the planned reforms. They expect that the whole system will conform to the given directions and ultimately will change accordingly. In reality, it does not happen, even with additional corrective actions. The theoretical premises and the research conducted for explaining the facts, even though they have revealed crucial aspects and variables that indeed play significant roles, ultimately were proved inadequate. This shortage is reflected in both the statistical modeling and the theoretical interpretations (Stamovlasis 2016a). The outcomes are not linear sums of the contributing components. The main position in this paper is that the weak points of the traditional scientific approaches in theory and practice are just the underlying assumptions for the educational reality, that is, the linear, reductionistic and mechanistic views. Aiming to make a substantial contribution to the field, a different epistemological framework is fostered reexamining the issues in questions under the prism of Complex Dynamical Systems Theory. The present work is part of a general project working on CDS and focuses on the degree of readiness of teachers for an educational change.

1.2 Education as a complex dynamical system

Educational issues are treated by the traditional philosophical (ontological and epistemological) approaches as complicated rather than complex. Snowden & Boone (2007) made the distinction between simple and complicated saying that the *simple* is in the realm of the ‘known’, while the *complicated* that is in the realm of the “known unknowns”, the expertises, the analytics. Both however, obey the cause-and-effect rule, that is, the Cartesian view of causation, whereby a simple sequential relation exist between cause and effect. The *complex* on the other hand, is in the realm of unpredictability and flux. Human systems belong to this category. Education is the place where many entities coexist, such as: students, teachers, content, means, time, goals, and context; they interact with each other within an active structure that is ontologically an interconnected *network* (Ni & Branch, 2008; Snyder, 2013). The underlying processes could be characterized as complex dynamical systems (CDS) and studied within this perspective. Among the advantages of the CDS approach is that it offers "*a rich and broad vocabulary that can capture the processes of change and interaction between individuals and wider organizational formations*" (Koopmans & Stamovlasis, 2016, p.1). Within this framework, which provides both the description language of procedures and the methodological tools for their study, the nonlinear and unpredictable nature of educational processes becomes visible, and of the associated phenomena are better understood (Biesta & Osberg, 2010; Cochran Smith et al., 2014).

The CDS theory has gained the interest of many researchers in the field of education (e.g. Osberg, Biesta, & Cilliers, 2008; Davis & Sumara, 2010). The

review of the entire literature is beyond the scope of the present paper, however, there are some representative works from various areas: learning interactions within the classroom (e.g. Pennings & Mainhard, 2016; Steenbeek & Van Geert, 2013), educational psychology (e.g. Sideridis, Stamovlasis & Antoniou, 2016), dynamical view of high school attendance (Koopmans, 2015, 2016), teacher career decision making (Stamovlasis & Vaiopoulou, 2017), to mention a few. Following the growing body of contributions, this work primarily introduces the CDS approach to the field investigating educational reforms and reexamines old issues and concerns with main position that *changes* cannot be studied within traditional linear reductionistic frameworks.

1.3 Reforms and resistance to change

Scheduled top-down changes in an organization usually causes intense reactions, originated mainly from syndicates or workers' associations, expressing worries about how the pending changes can affect the worker (Bateh, Castaneda, & Farah, 2013). The reactions appear as "resistance to change" and they are mainly driven by the anxiety and the concern of the organization members regarding the stability of their job position and their professional development. Besides insecurity, some workers show unwillingness to be involved in processes of learning and developing new skills (Marsh, 2001). With respect to schools, people need a convincing rationale for the changes, which is sometimes but not always provided. Changes in schools can be achieved merely if they are in accordance to the views, attitudes and needs of the teachers (Terhart, 2013). Resistance to change is usually confronted by means of negotiations, since it indicates rupture of trust (Ford, Ford, & D'Amelo, 2008). However, negotiations seldom lead to consensus because the two sides have different aspirations and thus the polarization is reinforced. The predominant tendency to address polarization is the imposition of change by the leadership, which almost inevitably leads to intense conflict and then to the failure of the proposed policy (Michiotis & Cronin, 2011; Vakola, 2014).

The above apply also to educational reforms. Globally there are several exemplary educational reforms that failed: e.g. the English teacher's certification in South Korea, where educators were involved in multiple types of low-profile opposition that had an effect on the destiny of the certification (Tae-Hee, 2017); the vague application of self-evaluation in schools of Lower Saxony, Germany, where conservative parties as well as several teacher unions have for a long time been able to prevent radical school reforms (Hartong, 2012: 749); the teachers evaluation reform in Mexico, where the Mexican teachers' union have strongly reacted against what they erroneously perceive as "the beginning of the end" concerning additional demands for moving teacher education to the university level (Tatoo, Schmelkes, Del Refugio-Guevara & Tapia, 2006: 268).

The explanations of the above failures were rather fragmentary and limited to certain dimensions of education systems. Research probing the factors affecting the processes of change in education, certainly involves psychological variables, attitudes, personality traits and moreover wider organizational factors the interactions of which becomes even more complex (Hayward & Spencer, 2010). At the observable level, the behaviors are not always consistent in time and not easily interpreted via reductionistic views. The plethora of factors involved are hard to be mined and understanding the underlying phenomena becomes difficult based on the accumulated knowledge acquired in the linear regime.

Summarizing the above, one recognizes that attempts toward reforms always confront forces of resistance to change. Theoretical developments in the field in order to proceed with conflict resolution have proposed a shift from the notion of resistance to change toward the notion of readiness for change (Armenakis, Harris, & Mossholder, 1993, p. 681). However the resistance to change as attitude and action precedes, it is a part of the existing empirical framework, and demands a modeling approach to be studied. Moreover, revealing the crucial factors that can be incorporated in an effectual explanatory model is the prerequisite and by far needed.

1.4 Teachers' evaluation: The crucial issue for reform

Teacher evaluation is an extremely thorny issue in the education. The reasons why their assessment, at international level, is at the heart of the discussions and reforms are: the essential role of teachers in the learning process; the pursuing of their professional empowerment; the increasing pressure since the 1990s for accountability in education; the shifting of the assessment to a more neo-liberal framework that draws ideological foundations from the market culture (Murphy, Hallinger, & Heck, 2013). Evaluation process encompasses high difficulty in designing and implementation, while a long-term goal is to develop a reliable evaluation system based on firm theoretical foundations (Kyriakides et al., 2006). While educational researchers and scientists show readiness to support an evaluation system, educational community does not. Teachers are poorly prepared and even unwilling to accept a generalized public involvement in their own affairs and their professional assessment (Conley et al., 2016).

While in most countries early assessment processes have been developed, the issue in the Greek educational system-since 1982- stayed behind for a variety of reasons, mainly political and ideological. Interestingly, no formal legislation has been completed due to intense reactions; even the most recent efforts failed, demonstrating once again the 'inertia' of the system and its 'resistance' to change. The present work focuses on that system's behavior.

2. Rationale, Hypotheses and Research Outline

In this section, the objectives and the research questions are presented along with the outline of the research design. Since the project is at the first stages, only some preliminary results will be reported highlighting the use and the advantages of the nonlinear methodologies, and the theoretical and practical implications.

Given the enduring failures of the Greek education system to succeed planned reforms and the incapability of the existing theoretical frameworks and the linear methodologies to provide a comprehensive explanation, reaching a new approach is very desirable. In the present research the traditional epistemology with mechanistic view on the education-system's functioning has been questioned and replaced by the complexity theory paradigm. In a previous section, the ontological description of an educational system consisting of parts which interact within network structures, showed that basic CDS assumptions can definitely be made, whereas the implementation of nonlinear methodologies is correspondingly essential.

In the outlining the present inquiry, there are two phases. The aim of the first phase was to reveal teachers' attitudes, beliefs and alternative conceptions about *educational assessment*, variables which affect teachers' behaviors and their readiness for an effective educational change. In revealing and accessing the above mentioned latent variables, the *focus group* approach was chosen as a suitable process of data/information collection. The working hypothesis behind this choice was that a brain-storming-like interaction process can facilitate the revealing of the above intangibles, such as beliefs and alternative conceptions. The verbal dynamical interactions recorded from the *focus group* sessions can be analyzed by means of nonlinear methods and tools, which make possible to characterize the discourses in terms of macro- indexes (e.g. entropy) and moreover to bring into surface the crucial latent beliefs that affect teachers' positions and actions related to the issue under study.

In the second phase, having revealed the latent variables in question, the development of a survey instrument, a questionnaire, is planned, via which measurements at a larger scale could be carried out. In this pilot study, a similar valid instrument from the existing literature was implemented, which embraces some of the crucial variables in question, and partially satisfies the needs of the present research. The relevant variables were subsequently used for modeling teachers' position change regarding educational reforms.

Probing the apparent inertia of the Greek educational system as far as its adaptability to new challenges, a conceptual model is used to visualize the interplay among the various factors. This is the model of *force-field-dynamics (FFD)*, where *forces to change* versus *resistance to change* co-exist and co-act on system's parameters. This idea has been known for decades (Lewin, 1947), but it has not

been successfully tested with empirical data by implementing predictive variables, because the linear modeling is inadequate for systems where two opponent forces act concomitantly. The *FFD* model, though, might work better with the proper variables and nonlinear models, among which catastrophe theory models are the most applicable (Stamovlasis, 2016a). Specifically, cusp catastrophe model which implements two control variables operationalizing two antithetic mechanisms or opposing processes, is proposed in the present paper, and thus, the working hypotheses are related to potential nonlinear effects in teachers' attitudes and positions regarding a pending educational reform.

3. Method

3.1 Measurements and procedures

3.1.1 Focus groups

In the first phase, seven *focus groups* comprised of 3 to 5 people were examined. The participants were teachers, of primary and secondary schools, who voluntarily took part in focus groups of about one-hour duration. The relatively small number of group members was preferred in order to enhance the chance for everybody to express his/her positions and achieve the fullest possible in-depth discussion of the issue, while maintaining the benefits of the focus group (Krueger, 2000; Sandström-Kjellin, 2008). The verbal interactions in the focus groups were audio recorded and transcribed.

The symbolic time series were obtained from a coding process which started inductively by two independent researchers. They studied carefully the transcribed material and proposed a final coding scheme that subsequently was applied to all discourses. The coding process distinguished utterances, which were meaningful segments of the discourse and expressed information related to the research questions. Examples of single codes are: P=Positive attitude, F=Fear, N= Negative attitude, A=Anger. A two-digit code for each utterance includes the first digit indicating the identity of the speaker (teacher (K) or principal (D)): DP=Principal talks with positive attitude, KN= teacher talks with negative attitude. Moreover, a multiple coding scheme is possible to record and analyze including other individual reactions or attitudes expressed during the discourse. For instance a four-digit code for each utterance might include the speaker, attitude towards evaluation, emotions, and perception of the current situation.

3.1.2 The survey research

In this pilot study, the survey research was carried out with the *Resistance to Change Scale* (RTC; Oreg, 2003; Oreg, et al., 2008), adopted for the needs of the

present research. The participants ($N=209$) were teachers from primary and secondary education, who were asked to answer a questionnaire, with 5-points Liker-type items, which, among others, includes the dimensions *Routine seeking* and *Emotional reaction*, along with items measuring teachers *Position*. *Routine seeking* ($\alpha=0.81$) measures the degree to which a subject like things to stay as they are (e.g.: ‘I generally consider changes to be a negative thing’, ‘I’ll take a routine day over a day full of unexpected events any time’, ‘I like to do the same old things rather than try new and different ones’). *Emotional reaction* ($\alpha=0.79$) measures the degree to which a new situation affect his emotional state (e.g.: ‘If I were to be informed that there's going to be a significant change regarding the way things are done at school’, ‘I would probably feel stressed’, ‘When I am informed of a change of plans, I tense up a bit’, ‘When things don't go according to plans, it stresses me out’. The crucial question (how strongly you support an ensuing educational reform) operationalized teachers’ *Position* on the issue in question.

3.2 Analysis of the focus–groups discourses

The empirical data, which were coded verbal interactions consisted of symbolic sequences or time-series of the type: AABBB Δ CAABAEAA $\Delta\Delta$ BBBEAABAEAA Δ . The symbols could represent utterances, people or characteristic of the participants. Orbital decomposition analysis, ODA, a method based on symbolic dynamics designed for time-series analysis for categorical data (Guastello, Hyde & Odak, 1998; Guastello, 2002) was applied. In ODA a set of indexes can be calculated, which convey information about various aspects of the discourse and its dynamics. A simple and useful index obtained from ODA is the *proximal recurrence* of various string lengths. High recurrence of certain proximal patterns, which according to coding scheme express certain opinions, emotions, attitudes or dysfunctional beliefs, indicates the prevalence of the relevant latent factors. Moreover, ODA includes analyses of theoretical interest associated with the nature of discourse processes and are useful in their qualitative and quantitative characterization. These are the following: *Topological entropy* (H_T) describing the deterministic *nonrandom complexity* for the time series and the *Lyapunov exponent* (D_L), which is a measure of chaoticity are some examples. Moreover, ODA provides the frequencies of repeated patterns of any string length. Details of the mathematical formalism and conceptual descriptions could be found in original papers (e.g. Guastello, 2009; Pincus & Guastello, 2005) or in resent educational research applications (e.g. Stamovlasis, 2016b). Another measure of complexity is the Shannon entropy (H_s), defined for a set of categories with unequal odds of occurrence by the equation (1):

$$H_s = \sum_{i=1}^r p_i [\ln(1/p_i)] \quad (1)$$

Where i ($i=1$ to r) is a categorical outcome and p_i is the associated probability (Shannon, 1948). *Shannon entropy* reflects the degree of novelty produced within a categorical time-series and it is useful to compare discourses of the same kind and content.

Moreover, an interest inquiry is to examine if, and in which cases, those time series of verbal turn-taking patterns conform to *inverse power law* distribution (iPL). The iPL, expressed by the equation 2, connects the magnitude of a recurrence phenomenon with the frequency of occurrence.

$$S \sim f^{-\beta} \quad (2)$$

The slope of the corresponding log-log graph, β , is named the *fractal dimension*, which is also a measure of complexity, denoting a dynamical process.

3.3 Cusp Catastrophe Analysis

Cusp catastrophe analysis is realized via a stochastic model based on mathematical equations, which express the probability density function or the derivatives of the basic potential function $f(y; a, b)$:

$$f(y; a, b) = ay + 1/2by^2 - 1/4y^4 \quad (3)$$

The above equation describes a dynamical system in which two opposing mechanisms or forces are applied and an optimizing function is operating (Gilmore, 1981). The whole process is driven by two control variables: (**a**) is the asymmetry factor and (**b**) is the bifurcation factor. Figure 1 is the graphical representation of the cusp model and it is described by the derivative of equations (3), while it is used to facilitate interpretation of the cusp model. The cusp catastrophe is a suitable approach for modeling *force-field-dynamics*, since the two control variables operationalize opposing processes, such as those visualized for reform resistance.

The calculations with cross-sectional data is based on the probability density function (*pdf*) (equation 4), where the least squares method (Guastello, 2011) or the maximum likelihood (Cobb, 1998; Grasman, van der Maas, & Wagenmakers, 2009) could be used.

$$pdf(y) = \xi \exp \left[-\frac{1}{4}y^4 + \frac{1}{2}by^2 + ay \right] \quad (4)$$

The detection of a cusp structure and bifurcation effects in the empirical data has important implications for theory and practice.

4. Results

4.1 Focus groups

Among the plethora of latent variables revealed via the focus–group interaction processes, were two already well-known from the literature: *Routine seeking* and *Emotional reaction* (e.g., Oreg, 2003). They are dimensions included in *Resistance to Change Scale* and were chosen for further statistical modeling (see next section). Discourse analyses via ODA, provided macro-characterization of the corresponding verbal interaction processes. Sessions with higher values of Shannon entropy (H_s), indicated higher degree of novelty and they were associated with richer content as far as the variety of information regarding the latent variables under investigation. The degree of turbulence or chaoticity measured with the Lyapunov exponent was also a mean to characterize these brain storming situations and correlate them their effectiveness. Solid conclusions will be probably established with a larger sample, however it is worth reporting that, even though this was not always the case, intense and content-rich discourses were characterized by time series of verbal turn-taking patterns that conform to *inverse power law* distribution (iPL).

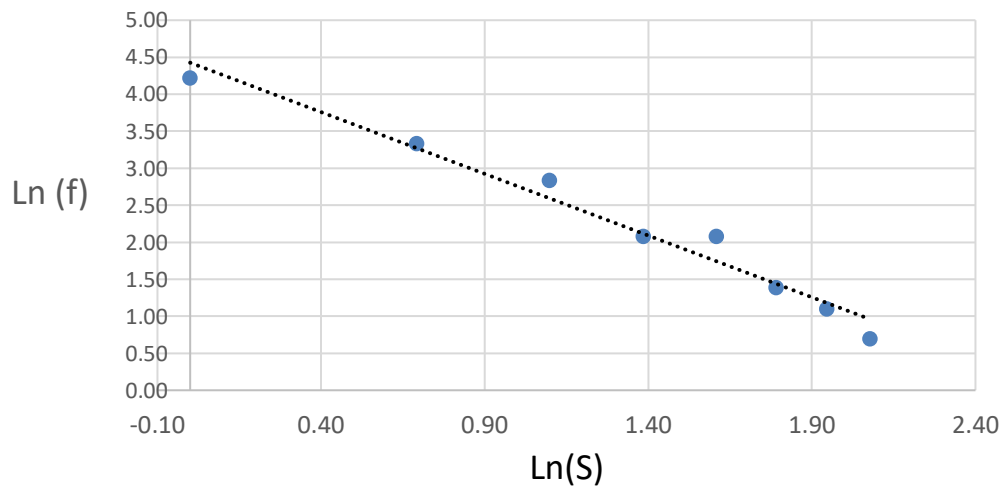


Figure 1. A log-log scale plot of frequency versus the magnitude of the utterance-recurrent phenomenon. The fitted line ($R^2 = .97$) suggests an Inverse Power Law distribution with $\beta = -1.66$ ($p < 0.001$).

Figure 1 depict a case describing the log-log relation between S, the magnitude of the recurrence phenomenon (measured by the number of recurrences for a given

pattern of utterances) and f is the frequency at which each particular value of recurrence is observed. (Pincus & Guastello, 2005). The negative slope of the graph, the *fractal dimension*, specifies that there are few high recurring patterns and many low recurring patterns during the discussion session. The fitted line ($R^2 = .97$) with slope $\beta = -1.66$ ($p < 0.001$) indicates that the process is functioning within the dynamic regime, (Kauffman, 1995; Waldrop, 1992). It is imperative to stress here that from strictly statistical point of view, a fitting procedure should include comparison of other competitive models, however the choice of iPL is purely theoretical and it is dictated by CDS framework, which congruently provides robust and consistent interpretations. These finding has significant theoretical implications concerning the interaction processes and specifically the cooperative learning sessions in educational context (Stamovlasis 2016b).

4.2 Cusp catastrophe model

Empirical data from measurements of the dimensions *Routine Seeking* and *Emotional reaction*, were explored via cusp catastrophe analysis based on equation 4. Tables 1 shows the results using least squares (LS) as optimization method depicting slopes, standard errors, t -tests and model fit statistics for cusp and the alternative model. In the linear model predicts a small portion of the variance (0.09%) in the dependent variable [Adjusted $R^2 = 0.09$, $F = 10.12$, $p < 0.001$]. Both weights of the predictors: *Routine Seeking*, (a), [$t = -2.65$, $p < 0.0001$] and *Emotional reaction*, (b), [$t = 1.98$, $p < 0.05$] are significant. The cusp model was,

Table 1. The cusp model estimated by least squares method: Slopes, Standard Errors, t -tests and Model Fit statistics for Cusp and the alternative linear model. *Position on Assessment* the dependent variable *Routine seeking* as asymmetry and *Emotion reaction* as bifurcation.

	Model	Adj R ²	b	seb	t	Model F
Depended variable: Position	Linear Model	0.09				10.12***
	<i>Emotional reaction b</i>		-0.16032	0.084	-1.98 #	
	<i>Routine Seeking a</i>		-0.22321	0.083	-2.655**	
	Cusp	0.67				69.54***
	Z^4		0.02521	0.0051	4.94***	
	bZ^2		-0.06732	0.0223	-3.02**	
	aZ		-0.03291	0.0118	-2.79**	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, # $p < 0.10$ (one-tailed), ns =non-significant.
a (asymmetry) = Routine Seeking; b (bifurcation) = Emotional Reaction.

however, superior explaining 67% of the variance [$R^2 = 0.67$, $F = 69.54$, $p < 0.001$]. Each of the terms in the basic cusp model significantly predicted change in the behavioral variable: the cubic term [$t = 4.94$, $p < 0.001$], the bifurcation factor, *Emotional reaction* [$t = -3.02$, $p < 0.001$] and the asymmetry *Routine Seeking*, [$t = -2.79$, $p < 0.01$].

The cusp structure was also confirm by using the maximum likelihood. The two approaches implement different optimization algorithms, use different fit indexes and can be used complementarily. Further details on the cusp modeling approaches could be found in Stamovlasis (2016a).

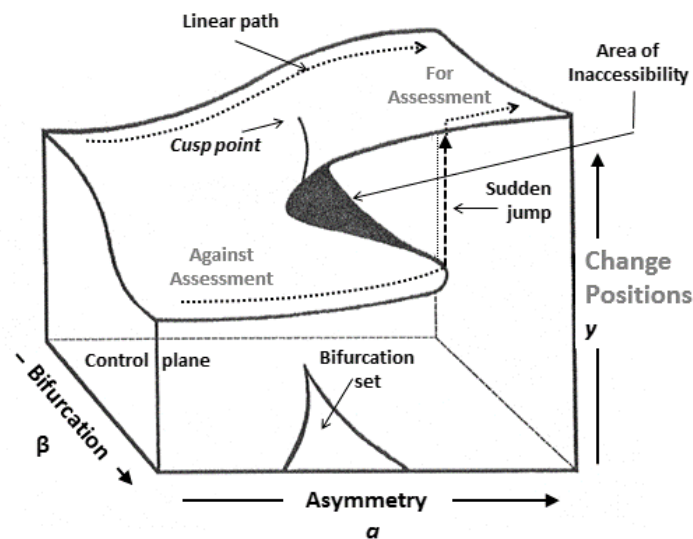


Figure 2. Representation of the cusp catastrophe model. *Position on Assessment* is the dependent variable. *Routine seeking* (a) is the asymmetry and *Emotion reaction* (β) is the bifurcation factor.

5. Discussion and Concluding Remarks

This paper reports the methodological outline and some preliminary results of a research project working within the Complex Dynamical System epistemological framework in the area investigating educational reforms. It focusses on finding crucial latent variables that shape teachers' attitudes and drive their corresponding behaviors and in addition seeks empirical support for forms of nonlinearity, such as discontinuities and bifurcation effects. *Focus-groups* were used for collecting empirical evidences that reflect the presence of the latent factors contributing to resistance to change. This method operated as a mining process and it has many advantages over similar approaches, such as interviews, because it has the least researcher involvement. While the *focus-group* method is widely used, this approach based on verbal interaction dynamics and nonlinear analysis is quite

novel. Besides the main goal of revealing the crucial variables in question, the focus-groups study provides the opportunity to carry out analyses of theoretical interest. For instance, empirical evidences of iPL distribution, novelty measures of information entropy and other chaotic indexes, which are sought to characterize the brainstorming sessions in focus groups. To this end, a new method of data collection was introduced as a contribution of CDS to the field. The present findings are probably limited by the fact that the project is at its initial stage, however, the results are encouraging and promising for further methodological and theoretical development.

In addition, equally valued is the finding that the empirical data conformed to cusp catastrophe structure, which within the nonlinear framework consists the fingerprint of complexity. Bifurcations are dynamic effects which cannot be explained by any theory outside of the CDS framework (Nicolis & Nicolis, 2007). Interpreting the cusp structure, it could be said that the dependent variable, teachers' *Position*, has a negative linear relation with *Routine seeking*, that is, less routine seeking is associated with more receptivity toward change. This relation holds at low values of *Emotional reaction*, the bifurcation factor, while beyond a threshold value, a splitting effect is taking place and the dependent variable becomes bimodal. The two modes represent the *For-reform* and the *Against-reform* positions respectively. Passing that critical value, the system oscillates between the two behavioral modes and it is said that it enters the area of unpredictability since transitions from one mode to the other can occur. The implications of this is that the expected changes in the system might not be smooth and linear but could be discontinuous transitions from one state to the other.

Theoretical conjectures should not ignore, but take into consideration the bifurcation role of certain variables and anticipate that the outcomes cannot be expressed as linear sums and occur in a smooth linear mode. In a CDS sudden transitions might emerge via a self-organization process. Practically, one can evoke that changes in an educational system might occur in a nonlinear fashion, whereby small input might result to a great outcome - a potentially desirable state. Thus, revealing the crucial nonlinear elements of the system allow the researcher and further the policy maker in a decision-making process to make the appropriate choices that can facilitate relevant education reform driven by complexity theory thinking.

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