A Nonlinear Dynamical System Perspective on Team Learning: The Role of Team Culture and Social Cohesion

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Abstract. This paper examines team learning within a nonlinear dynamical system (NDS) perspective. Research has successfully identified various conditions that promote learning behaviors in teams. In the present study, our focus is on the role played by team culture and by social cohesion as supporting conditions of team learning. Previous studies revealed that a culture oriented to learning tends to promote the adoption of team learning behaviors in the group. Results concerning the role played by social cohesion in team learning is, however, less clear. Indeed, while social cohesion might promote learning behaviors because it increases the willingness to work together and to help each other, high levels of social cohesion could also lead to uncritical acceptance of solutions. The complex relationship between social cohesion and team learning behaviors led us to study it under the NDS framework. Using the dynamic difference equation model, the present research proposes a cusp catastrophe model for explaining team learning, implementing the team culture as the asymmetry variable and social cohesion as bifurcation variable. The sample of the present research is constituted by 44 project workgroups, and data were collected at two moments of the life cycle (half-time and end) of teams, with single-item visual analogue scales. Results reveal that the cusp models are superior to the pre-post linear models by explaining a larger portion of the variance. In addition, the cubic term, the bifurcation effect and the asymmetry term are statistically significant. Social cohesion acts as a bifurcation factor, that is to say, beyond a certain threshold of social cohesion, groups that have the same cultural orientation might oscillate between two attractors, the modes of high and low learning behaviors respectively. These results suggest that a small variation of social cohesion causes the system to enter an area of unpredictability in terms of team learning, where sudden shifts

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in the outcomes might be expected. Leaders and members need to monitor the levels of social cohesion of the team, to avoid phenomena like groupthink, which jeopardizes the implementation of learning behaviors, such as the exploration of different opinions or error discussion.

Keywords: Cusp model · Nonlinear analysis · Team learning · Team cohesion · Team culture

1 Introduction

Organizations worldwide face, more than ever, the need to continually rethinking their practices in order to succeed and to be sustainable over time. The ability to reflect, to experiment with new ways, rejecting old models and adopting more appropriate strategies, i.e., the capacity to learn, emerges as a fundamental process for individuals, teams and organizations [1]. As teams are the cornerstone of modern organizations [2], team learning has a central role in the team and organizational success [3–5].

According to Edmondson, Dillon, and Roloff [6], team learning might be conceptualized as performance improvement (i.e., as an increase in knowledge), as task mastery (i.e., the ability to coordinate team members' knowledge to accomplish tasks) or as a process of collectively sharing, discussing and reflecting on experience. In the present study, team learning is conceptualized as a process that involves different behaviors: seeking internal and external feedback in order to evaluate the group functioning and results; exploring new approaches and sharing and debating ideas; testing new paths to achieve the teams' aims; reflecting on the team behavior and results; analyzing errors and discussing ways to prevent them [7].

Due to the key role that team learning has in organizations, studying the conditions that enable teams to learn is of crucial importance for both research and practice. In the present study, our aim is contributing to the body of knowledge of team learning, by analyzing the antecedents of this team process adopting a nonlinear dynamical system (NDS) perspective. The NDS approach is the "study of how complex processes unfold over time and is sometimes known as chaos theory or complexity theory" [8]. It is not simply a group of methods for nonlinear data analysis, rather it is a set of concepts that describe ways by which a system can change over time [9]. The theoretical concepts and methodological tools of the NDS approach have been applied in several fields of social and behavioral sciences, namely in the study of group dynamics (e.g., [10–13]). Indeed, in order to acknowledge the complexity of teams, one should adopt perspectives and methods that recognize the nonlinear nature of the relationships that take place in the team context [14].

Research has successfully identified various conditions that promote the learning process in teams. It has been shown that, among other variables, team culture, that is, team members' beliefs about "the way things are done" in the group could have this kind of influence [5,15]. Team culture is an emergent set

of norms, values and actions that team members develop and share [16] and is characterized by a certain stability over time. Indeed, when a hint, a value or a rule is implemented and works repeatedly and successfully [17] becomes a guide for action, influencing the way team members behave and interact with each other. Since team learning is a set of behaviors that involve sharing, reflecting and discussing, it is expected that different team cultures will have distinct impacts on the learning behaviors that are adopted by the team. Therefore, in teams where the shared values are oriented to learning, learning behaviors will be more frequent than in teams with a team culture less oriented to learning [15]. Accordingly, a positive linear relationship is expected between team learning orientation and team learning behaviors.

Team cohesion, which can be defined as the result of all the forces acting on members to remain in the team [18], has been also identified as a supporting condition for team learning [19]. Team cohesion has been conceptualized as a multidimensional concept, being the two-dimensional model, which distinguishes between task and social cohesion, widely accepted [20,21]. Previous studies found that task cohesion, i.e., the shared commitment among members to achieve goals that requires collective efforts, is a supporting condition of team learning behaviors (e.g., [22]). Results for the role of social cohesion, which concerns emotional bonds, such as liking, sense of belonging, caring, and closeness among group members, are, however, less clear (e.g., [3,19,23]). By promoting the desire of being part of the group, social cohesion might increase the levels of resources (e.g., cognitive, temporal) that team members invest in the team, increasing team learning behaviors. At the same time, social cohesion may lead to uncritical acceptance of solutions, namely due to team members' fear of being rejected. The studies reviewed by Bell *et al.* [19] pointed to this direction, suggesting that cohesion enhances team learning processes, but at the same time learning may be impeded when teams are characterized by excessive social integration or when cohesion is not supplemented with processes that facilitate the critical processing of information.

Thus, the ambiguous findings regarding the relationship between social cohesion and team learning behaviors that emerged from previous studies using linear models led us to study it under the NDS framework, in order to analyze social cohesion as a bifurcation variable, using cusp catastrophe modeling. Catastrophe models enables the analysis of discontinuous, abrupt changes in dependent variables resulting from small and continuous changes in independent variables [24]. In particular, cusp catastrophe models describe change between two stable states of the dependent variable (i.e., order parameter) and two independent variables (i.e., control parameters). The possibility of modeling discontinuous changes is one advantage of this technique that can contribute to the knowledge about the complex relationships between either team processes or emergent states with team outcomes [25].

Thus, under the scope of the NDS approach, the purpose of this study is to test a cusp model, summarized in Fig. 1. Team learning is considered the dependent variable or the order parameter, which is influenced by team culture

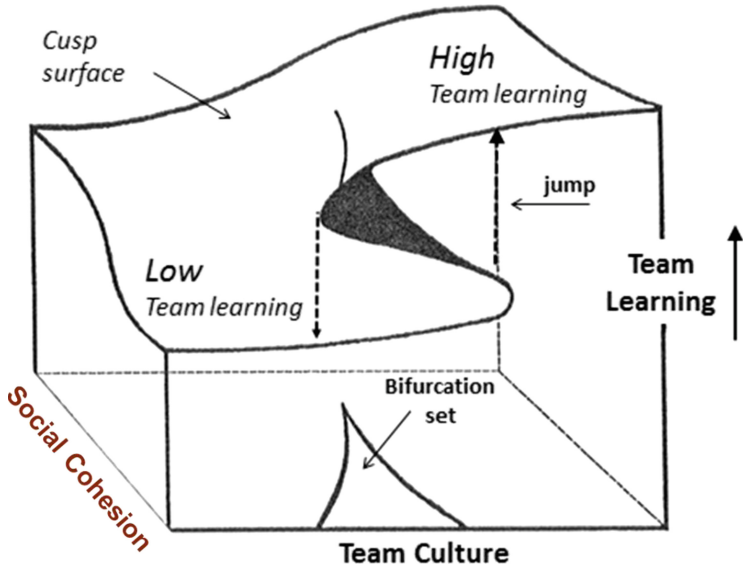

Fig. 1. A three-dimensional display of the cusp catastrophe response surface of team learning as a function of team culture (asymmetry) and social cohesion (bifurcation).

and social cohesion (independent variables or control parameters). Based on the literature presented above, it is expected that team culture will maintain a linear relationship with team learning over time. However, it might be positive or negative, depending on the characteristics of the culture that is developed by the teams. Hence, team culture will be considered the asymmetry variable in the cusp model since this type of control parameter is related to the order parameter in a consistent pattern [25]. Since the inconsistency of results concerning the relationship between social cohesion and team learning might be a clue for the existence of a nonlinear and complex relationship, social cohesion is a candidate for the role of bifurcation parameter.

2 Materials and Methods

2.1 Procedure and Participants

Data were collected on 44 teams made up of undergraduate students of engineering and technology courses of one Portuguese university. These courses are organized according to the Problem Based Learning (PBL) model. The teams (randomly constituted) have a semester to develop their work, which consists of a project that gives an answer to a current organizational need. Each group has a tutor that acts as a facilitator, guiding the group when needed. Data were collected at the middle (T1) and at the end (T2) of the academic semester. In T1, team members were asked about what had occurred since the beginning of

the group till that moment (roughly in the half of its allotted time). Similarly, in T2, participants were asked to respond based on what had happened since the last data collection. At both moments of data collection, data regarding team culture and team learning behaviors were collected in a team meeting, where members answered a questionnaire together by reaching a consensus. Information concerning social cohesion was obtained from team members individually.

Teams were composed of 4 members on average (SD = 0.9; min = 3, max = 6). The mean age was 24 years (SD = 6.5), 88% of the team members were male and the majority were full time students (78%). Finally, 31% of students were attending the first year, 7% the second year and 55% the third year of the degree.

2.2 Measures

All constructs were measured through single-item measures and Visual Analogue Scales (VAS). In the case of multidimensional constructs (such as, team culture and team learning behaviors) a single-item measure was created for each dimension following the criteria suggested by Fuchs and Diamantopoulos [26]. The use of this kind of measures is in line with Roe, Gockel and Meyer [27], which state that multi-item measures are not the best option for capturing change in groups over time and that single-item measures and graphic scales are suitable alternatives in longitudinal studies.

These single-item measures were submitted to a set of experts and to three pilot studies for estimating content and face validities, respectively, and no problems have been identified, as reported in Santos, Costa, Rebelo, Lourenço, and Dimas [28]. To overcome some psychometric shortcomings of single-item measures and raise the confidence in their use in this study, convergent validity studies with the original instruments on which these measures were based [26], were carried out.

Team Learning. To measure the occurrence of team learning behaviors, five single-item measures were developed based on the multi-item Team Learning Behaviors' Instrument [29], which in turn is based on Edmondson's [7] types of learning behaviors. Thus, our five single-item measures correspond to five team learning behaviors: exploring and co-construction of meaning, collective reflection, error management, feedback seeking, and experimenting. An example of this single-items is the item developed for assessing error management behavior: "we discussed collectively our errors and the best way to avoid them". In the five single-items, teams had to mark on a VAS, from 0 (*never*) to 10 (*always*), the occurrence of the respective learning behavior. Concerning validity studies, a sample of 212 Portuguese higher education students was used. The correlations between each single-item measure and the respective multi-item dimension of the Team Learning Behaviors' Instrument ranged from .48 to .68. These results offer satisfactory confidence in these single-item measures.

Team Culture. Four single-item measures were developed based on the FOCUS questionnaire [30], an international questionnaire that measures organizational culture according to Quinn's [31] competing values model. Thus, four cultural

orientations were assessed in each group: support (emphasizes the establishment of cohesion and commitment in the group), innovation (highlights flexibility, change, and creativity), rules (values internal stability through efficiency and coordination), and goals (is oriented towards performance and goals achievement). An example of these single-items is the one developed to assess support orientation "our team was characterized by: mutual understanding, acceptance of failure, mutual trust, mutual support when carrying out tasks, good interpersonal relationships, good working atmosphere, mutual support in issues not related to work". Each group had to mark on a VAS, from 0 (*not at all*) to 10 (*absolutely*) the presence of each of the four cultural orientations. The sample used for the validity studies was made up of 250 Portuguese higher education students. Regarding convergent validity, the correlations between the single-item measure and the respective multi-item dimension of the FOCUS questionnaire (adapted for the group level) ranged from .53 to .67. All in all, and similarly to the single-item measures for team learning behaviors, these results are satisfactory.

Social Cohesion. One single-item was developed ("to what extent I felt part of this team?"), where team members' were asked to mark on a VAS, from 0 (*not at all*) to 10 (*absolutely*) their feeling. The choice of this single-item was based on the multi-item social cohesion scale of Sargent and Sue-Chan [32] and on the items that measure social cohesion of the Group Environment Questionnaire (GEQ), originally developed by Carron, Widmeyer, and Brawley [33] and adapted by Chang and Bordia [34] for use with work teams.

In terms of convergent validity, the sample of 212 Portuguese higher education students (previously mentioned for team learning single-items validation) was used. The correlation with our single-item measure with the GEQ social cohesion items was .43, offering sufficient confidence in its subsequent use.

2.3 Data Analysis Procedures

Mathematically, the cusp model is expressed by a potential function $f(y)$:

$$f(y/a, b) = ay + \frac{1}{2}by^2 - \frac{1}{4}y^4. \tag{1}$$

Equation (1) represents a dynamical system, which is seeking to optimize some function [35,36]. Setting the first derivative of the Eq. (1) to zero, it results in the Eq. (2), which represents the three-dimensional equilibrium response surface of the cusp model:

$$\frac{df(y)}{dy} = 0 \Leftrightarrow -y^3 + by + a = 0, \tag{2}$$

where a is the asymmetry factor and b is the bifurcation factor.

In the present research design, two measurements of team learning behaviors were carried out at the middle of teams' life (T1) and at the end of the teams' life (T2). These two measures in time facilitate the application of the dynamic difference equation modeling approach, which implements least squares regression techniques [37].

The specific equation to be tested in this study for a cusp catastrophe model is:

$$\Delta z = z_2 - z_1 = b_1 z_1^3 + b_2 z_1 SC + b_3 C + b_4 \quad (3)$$

where z is the normalized order parameter, while SC and C are the normalized bifurcation (Social Cohesion) and the asymmetry (Culture) at T1, respectively. The nonlinear model is tested against its linear alternatives, from which the most antagonistic is the pre/post model:

$$z_2 = b_1 SC + b_2 C + b_3 z_1 + b_4. \quad (4)$$

In order to test the nonlinear hypothesis that a cusp catastrophe is an appropriate model to describe teams' learning, the regression Eq. (3) should account for a larger percent of the variance in the dependent variable than the linear alternatives. In addition, the coefficients of both the cubic and the product terms in Eq. (3) must be statistically significant.

The sum of the five team learning behaviors was used as order parameter, since this sum shows how much learning behaviors each team engaged, independently of each form of learning. As aforesaid, social cohesion was implemented as bifurcation variable, while the four types of cultural orientation were implemented as asymmetry variables.

The unit of analysis in the present study is the group thus members' answers to social cohesion single-item were aggregated to the team level. In order to justify this aggregation, the AD_M index [38] was used. The average AD_M value obtained was 1.23 (SD = 1.22), which is below the upper-limit criterion of 2.0, allowing the aggregation of team members' scores to the team level.

3 Results

Table 1 presents the means, standard deviations and the correlation matrix for all variables under study.

Tables 2, 3, 4 and 5 show the regression slopes and standard errors for four cusp catastrophe models and their pre/post linear counterparts (one for each cultural orientation).

As can be observed, the four cusp models are superior to the respective pre-post linear models by explaining a larger portion of the variance (The R^2 values obtained for the cusp models are .43 for support culture, .42 for rules culture, .52 for innovation culture and .42 for goals orientation as asymmetry variables, against .19, .08, .18, and .19, respectively). Additionally, in all four cusp models, the cubic term, the bifurcation and the asymmetry are statistically significant, although support and rules orientations emerged as marginally significant asymmetry variables.

Overall, the results reveal the existence of a cusp structure in our data. The role of social cohesion as bifurcation variable is supported, revealing a nonlinear and discontinuous effect in the process of team learning.

Table 1. Means, standard deviations, and intercorrelations of study variables.

	Mean	SD	1	2	3	4	5	6	7
1. Social cohesion T1	7.87	1.54	–	–	–	–	–	–	–
2. Support T1	7.71	1.93	.13	–	–	–	–	–	–
3. Innovation T1	7.31	2.14	.23	.46***	–	–	–	–	–
4. Rules T1	6.69	1.97	.20	.55***	.48***	–	–	–	–
5. Goal T1	6.79	2.24	.08	.62***	.40**	.54***	–	–	–
6. Team learning T1	39.58	7.62	.04	.72***	.33*	.35*	.52***	–	–
7. Team learning T2	40.64	6.59	.15	.28	.17	.05	.05	.31*	–

Note: *** $p < .001$, ** $p < .01$, * $p < .05$.

Table 2. The difference model estimated by least squares regression: Model Fit for Cusp and the Linear Control. Support culture as asymmetry variable.

Model	Variable name	R^2	B	SE B	β
Pre/Post		.19*			
z_1	Team learning		0.43	0.15	.47***
b	Social cohesion		0.11	0.14	.12
a	Support		0.31	0.16	.31
Cusp 1		.43***			
z_1^3	Team learning		−0.13	0.04	−.50***
b	Social cohesion × z_1		0.38	0.15	.33*
a	Support		0.34	0.17	.29†

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

Table 3. The difference model estimated by least squares regression: Model Fit for Cusp and the Linear Control. Rules culture as asymmetry variable.

Model	Variable name	R^2	B	SE B	β
Pre/Post		.08			
z_1	Team learning		0.26	0.15	.26
b	Social cohesion		0.07	0.15	.07
a	Rules		0.09	0.15	.10
Cusp 1		.42***			
z_1^3	Team learning		−0.18	0.04	−.67***
b	Social cohesion × z_1		0.35	0.16	.29*
a	Rules		0.26	0.15	.22†

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

Table 4. The difference model estimated by least squares regression: Model Fit for Cusp and the Linear Control. Innovation culture as asymmetry variable.

Model	Variable name	R^2	B	SE B	β
Pre/Post		$.18^{*}$			
z_1	Team learning		0.30	0.14	$.30^{*}$
b	Social cohesion		0.16	0.14	.16
a	Innovation		0.25	0.14	.25
Cusp 1		$.52^{***}$			
z_1^3	Team learning		−0.21	0.03	$-.78^{***}$
b	Social cohesion × z_1		0.32	1.35	$.28^{*}$
a	Innovation		0.48	0.14	$.42^{***}$

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

Table 5. The difference model estimated by least squares regression: Model Fit for Cusp and the Linear Control. Goal culture as asymmetry variable.

Model	Variable name	R^2	B	SE B	β
Pre/Post		$.19^{*}$			
z_1	Team learning		0.36	0.15	$.37^{*}$
b	Social cohesion		0.10	0.14	.10
a	Goals		0.32	0.15	$.33^{*}$
Cusp 1		$.42^{***}$			
z_1^3	Team learning		−0.15	0.04	$-.57^{***}$
b	Social cohesion × z_1		0.32	0.15	$.27^{*}$
a	Goals		0.32	0.15	$.28^{*}$

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

4 Discussion and Conclusions

The findings of this study suggest that both team culture and social cohesion play a significant role in the team learning process, but that their contributions are different. The emergence of cusp structures with social cohesion acting as a bifurcation factor suggests that beyond a certain threshold of social cohesion, groups that have the same cultural orientation might oscillate between two attractors, the modes of high and low learning behaviors respectively. That is to say, a small variation of social cohesion could cause the system to enter an area of unpredictability in terms of team learning, where sudden shifts in the occurrence of learning behaviors might be expected.

Thus, this study supports the nonlinear dynamics of the learning process in groups, adding to the growing body of research that considers teams as complex, adaptive and dynamic social systems [39]. It also contributes to the small group research literature by presenting the role for social cohesion as bifurcation, which

might explain the discrepancies between various findings related to the effect of social cohesion on team learning behaviors (e.g., [19]). The idea that beyond a certain threshold, social cohesion might induce a bifurcation effect in team learning behaviors suggests that team supervisors and members should be aware that high social cohesion may lead to some phenomena, such as groupthink [40], which in turn, can lead members to avoid team learning behaviors, such as the exploration of different opinions or error discussion.

Regarding the asymmetry variable (group culture), the four cultural orientations analyzed (support, innovation, rules and goals) are positively related to the learning process in teams. Therefore, our results highlight that the presence of all the four orientations is important to the adoption of team learning behaviors, although the innovation and the goals culture assume a more prominent role in promoting learning in teams. This finding is in line with the operationalization of learning culture proposed by Škerlavaj, Štemberger, Škrinjar, and Dimovsky [41], who suggest that a learning culture predominantly covers support and innovation orientations, while it has aspects of goals and rules orientations.

Despite the contributions of this study, it also has limitations. Two of them are the sample size and the type of groups of the sample (project groups of students). Therefore, future studies should replicate the present findings with different teams, such as organizational workgroups, and with larger samples.

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