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A system dynamics approach to building team trust models: exploring the challenges

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Abstract. Learner models are one of the most important parts of any tutoring system. Due to the complexity of social systems, it gets more challenging to track personal data and to build a model of learner’s state when dealing with teams. This research suggests leveraging the available literature on team dynamics to make a system dynamics model of teaming. This model will offer a more accurate representation of the complexity involved. An example system dynamics model of team trust is created based on a previous qualitative study of team trust [3]. Its benefits include a holistic understanding of trust structure in teams, the ability to evaluate and predict trust level in teams given current individual states, and providing a testbed to evaluate multiple remedies to team issues. The authors suggest that using this system dynamics (SD) modeling approach with GIFT as the individual learner model is a valuable initial approach to adding full team functionality to GIFT.

1 Introduction

Sottilare et al. emphasize the important role of learner models in understanding the learner’s state in individual learning [1]. They expand this to team tutoring, where the input becomes relationships and states between individuals in teams. Fletcher and Sottilare also introduced the importance of team shared mental models and the difficulty of measuring traits like team trust, affect, or shared mental models [2]. Due to the complexity of individual differences and team member interactions, the team trust or shared mental model is not as simple as the sum of all individual states. For example, based on Wilson’s study [3], if considering the team trust level as the sum of individual trust, the issue of having cliques or subgroups in the team is not considered. While subgroups are forming, certain individuals may build increasingly high trust and communication with each other, and be not much connected with others. In this case, the sum of the individual trust level may be increasing, but in fact, having subgroups in the team will reduce the team identity and affect the overall trust level.
In this paper we will explore a different approach in modeling team trust level and its challenges.

2 Challenges of making a team trust model

The current trend in learner models is making inferences from data using machine learning techniques [4]. As suggested by VanLehn, this can happen through empirical techniques using learning curves or Bayesian knowledge tracing models. The problem in team learner models is that the learning environment has many changing variables that are not easy to record. Also, the same group of people can act differently based on the complexity of the task domain and the role assignment [1]. Considering the amount of variability in such systems, using pure machine learning techniques to elicit generalizable rules would require a very large amount of observations as a training set. As team tutoring systems are relatively new, there aren’t many available sources for data to build these models.

On the other hand, the dynamics of teams have been studied in different disciplines. Many of these studies assess and describe the dynamics of team characteristics development such as trust in teams [3]. Also psychologists have delved into more detail and evaluated the effect of personal characteristics and emotions in forming trust in teams [5,6].

Comprehensive literature reviews on team dynamics [7,8,9] offer a larger picture of what we know about dynamics of teams. This understanding can serve as a basis for forming dynamic team models. When the literature is reviewed, the amount and complexity of influencing factors can get overwhelming to analyze at once. This is due to the complexity of such systems arising from the amount of interrelations and feedback loops. Also, some elements of the system may change with a time delay. Due to our cognitive capacity and human’s mental models, analyzing such complex systems is almost impossible. It is necessary to have a method of presenting all the information and the relationships dynamically.

3 Possible approach

System dynamics (SD) is a method that provides a holistic view of complex systems. It has been widely used in different disciplines, mostly in business and policy making. SD is a helpful method in unraveling the unexpected behaviors
of complex systems. System dynamics models are developed to mitigate our limitations in analyzing the four main sources of complexity that we can’t easily comprehend: dynamic complexity (due to the rapid changing environment), feedback loops (interrelations of elements) in a system, time delay (in reactions) and the effect of stuck and flow (effect of accumulation and dispersal of resources) [10]. The authors believe the complexity of trust or shared mental models in teams is no less than any other complex social system.

An SD model can be helpful initially to give a holistic understanding of the dynamics of trust in teams. Once mathematical models are added to it, we have a simulation model that represents the overall trust state in a team. This model is now ready for validation. Once validated, given the current state of individuals, the model can evaluate the team trust level and simulate the future trend of trust under various scenarios. This means that while the tutoring system is gathering data on the individual states and trust between individuals, the SD model can serve as a team trust model. In addition, in cases where we have a trust issue in the team, there might be several possible ways to address that. With the simulation we can examine the results and select the most effective one. In the following section an example is given to demonstrate how a system dynamics model of trust in teams can be made based on analytic studies.

3.1 Previous Work

Similar approaches have been taken to model team dynamics and have shown the potential capacity of this method. Kefan et al. have used SD to model an entrepreneurial team’s risk-based decision-making [11]. The model considers many environmental aspects and also makes a number of assumptions about the logical way of decision making of team members. Their model provides a basis to analyze team decision making. However, its model is not based on specific literature on team communication.

Kim et al. have introduced a team performance model named team crystallization that simulates team performance at a nuclear installation [12]. The model uses as inputs the number of team communications, the state of the power plant, and different control strategies. Using sophisticated mathematical models and leveraging neural networks, the model is able to simulate the team performance under various conditions. This model, however, doesn’t study any other team elements than communication, and doesn't use feedback loops.
4 System dynamics team trust model example

As an example, a study on trust in distributed teams [3] is used to make a simulation model using Vensim software. According to Wilson there are three key factors that contribute to trust in such teams: group identity, relationship and familiarity. While Wilson's results are valuable, questions remain, such as, "If we changed multiple team factors at the same time, what will happen to trust?" and "What are the exact relationships between these factors? Does one contribute 60% to trust while the others contribute the remaining 40%?"

Lastly, this research doesn't address feedback loops, e.g., "If trust falls, does that impact team identity?" An SD model answers these questions. To construct an SD model, one needs both results like Wilson's to define the structure of the model, as well as case studies or expert opinion to assign the numbers. Once the model is made, the critical step of validation is required. The challenges of the validation process are discussed in section 5 of this article. An initial SD model based on Wilson's results is represented in Figure 1.

![Fig. 1. SD model of trust in teams, based on Wilson, 2013](image_url)

Each of Wilson's primary factors (shown as boxes) are affected by other variables that are represented in the model. The group identity, as explained by Wilson, is affected by the quality of team structure design, selection of team members and the level of respect the members give to differences. Also, role of strong leadership and training for diversity tolerance were mentioned as influencing elements in building team identity. The greatest threat to group identity was considered subgroups. The model represents all the mentioned relationships with the identity rate (arrow), which accumulates the group identity level over time, much like water filling a bucket. In this model low identity rate represents high subgrouping potential and vice versa. Feedback loops
in social systems play an important role in explaining complex behaviors of a
system. To include feedback loops in our model, we added the effect of trust
rate in group identity rate. This means that once trust is falling, the group
identity drops as well and vice versa. Also a feedback was added form trust
rate to communication rate. Similarly the two other elements of the system,
familiarity and relationship were modeled.

4.1 Simulating Team Scenarios

Assuming the model is validated, one of the benefits of an SD model is simu-
lating different team scenarios. For example, what if the leader changed part-
way through a project? To show some outcomes of this particular model, we
considered a scenario where the team design and member selection was not
done carefully, and thus subgroups form. Also, the team leader is not success-
ful in helping the team to build trust by enforcing communication or building
team identity. The model is set to simulate a period of 100 time intervals
which could represent 100 weeks. The trust level is a value between -5 and 5
starting at the initial state of 1. In this case the model shows the trend of team
trust level. Imagine noticing this negative trend in week 10 and considering
two options: either bring in a strong leader or have the members take a train-
ing intervention course. We test the effect of each and observe the results.
Figure 2 demonstrates the results under conditions of not doing anything, add-
ing a strong leader in week 11, having the team take an effective training
course in week 11, or doing both. In this case, doing both has the most influ-
ence. We can observe that in this model, the effect of a strong leader is higher
than the effect of a training intervention. Having this SD model, many other
scenarios can be tested as well.
This model is solely based on one article, and thus may not be the best representative of trust in teams. Additionally, this model needs to be developed further to incorporate the dynamics of shaping subgroups based on individual behavior. However, the model illustrates the power of an SD approach.

When modeling abstract measures such as trust, we are more interested in the overall trends (rising or falling) in teams, rather than the actual values. By assigning some initial state numbers to the input values, we can test the model under various scenarios. Ideally the initial state numbers will come from the individual learner models. In order to validate the model, the weights need to be validated by case study data or in the early stages of model implementation.

5 Limitations and challenges

Implementing a robust system dynamics model has some inherent challenges. First of all, every simulation model needs to be validated before the results can be considered dependable. The validation of the model requires actual data. Some research articles publish their collected data, and in this case, they
can serve as a validation source. Otherwise, in the early stages of running the tutor, the team learner model needs to be refined and tuned until validated. In addition, in the literature, some research studies may not agree with each other. In that case we may need to have different models based on those ideas and validate them during the initial testing process.

6 GIFT suggestions

The GIFT’s sensor module has a very strong framework for inputting several streams of sensor data. Also, the built-in learner module of GIFT enables using the individual data to update the learner’s affective state and learner model. However, for the team learner models, there needs to be a means to incorporate the SD model. Although these simulation models are easy to implement in simulation tools, it takes lots of effort to develop such a tool from scratch. Therefore, the authors suggest for the early stage of SD implementation, GIFT could facilitate an easy way to communicate with some existing SD software packages. However if using SD or other simulation models were proved to be helpful, then GIFT should consider incorporating such simulation as part of its learner model.

7 Conclusion

The structure of intangible and hard to assess features such as trust in teams is so complex that requires a holistic approach to understand and analyze. Using the analysis of teams in the literature and making a system dynamics model can first of all help the ITS team better in understanding the dynamics of the field. Secondly, the system dynamics simulation can construct a proper team learner model. Third, the model can serve as a laboratory to test several scenarios on teams and explore their behavior. Although validating such models may take some time, the validation process can happen in a shorter time than data-based models. Given GIFT’s ability to collect all the sensor data through the sensor module, adding the ability to incorporate SD learner models or communicate with external SD sources will enhance team learner models.

References


