A System Dynamics Model to Design a More Effective Education System

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Abstract

One of the educational systems used in different parts of the world is as follows: each session, new lessons and new homework are given to students. These assignments are not marked; instead, they are reviewed and if they do not meet the minimum acceptable standard, the student is obliged to do them again. This paper focuses on this education system and tries to show that setting a strict standard for homework acceptability does not necessarily promote learning. Not only this, but contrary to the original intention, it can increase students' workload and stress so much that it can harm their productivity and mental health. Literature review reveals there is no SD study on this subject, so this is the first attempt. The result is a qualitative model, which is a combination of the "rework" model of Cooper, the "burnout" model of Homer, and the "managing your workload" of Sterman. Probably the most effective first step in attempting to fight a complex problem is to understand its dynamic source. So, we are hopeful that this paper can be insightful for education policy-makers. Future research is needed to expand upon this initial model, and quantitative extensions may result in a better understanding. *Comments received by unknown reviewers are added to the end of the article, and we are sure they can be beneficial to people who want to continue researching this topic.*

Keywords

education system, assignments, rework, work pressure, workload, burnout, mental pressure, stress level, carrying capacity erosion, system dynamics, overshoot and collapse, shift the burden

Introduction

Education experts have always sought to design appropriate educational systems to maximize learning productivity and minimize the pressure students may experience. One of the methods used in many academic centers is that each session gives new lessons and new homework to students. These assignments may or may not be scored, each with its own advantages and disadvantages. For example, in a system that homework is graded, students are less likely to cooperate in doing homework, which can significantly help students learn more, especially students who need more help to digested the taught lessons. In the second educational system, however, homework is not marked. In this system, homework is reviewed, and if it does not meet the

minimum acceptable standard, the student is obliged to do them again. Only when all assignments get an “OK” will a student be allowed to sit the final exam.

This article intends to examine the second system. The research hypothesis is that setting a strict standard for homework acceptability does not necessarily promote learning. Not only this but contrary to the original intention, it can increase students' workload and stress so much that it reduces their productivity and mental health. In other words, it is usually underestimated that how much excessive strictness can be disruptive. A qualitative model is presented in the following to conceptualize this dynamic hypothesis. This model is a combination of three models: the "rework" model of Ken Cooper (Cooper, 1993), the "burnout" model of Jack Homer (Homer, 1985), and the "managing your workload" of Sterman (Sterman, 2000, P.159). Since Sterman's model is also in the realm of "education", it is useful to highlight the two main differences between the model presented in this research and the Sterman's model: (1) in Sterman's model, the goal is to compare the ant and grasshopper strategies and examine how procrastination can affect students' grades. Yet, the purpose of the model presented in this article is to show how too strict standards for the acceptability of exercises can reduce students' performance. In fact, it is implicitly assumed that students never intentionally procrastinate their assignments and always adopt the ant strategy (2) in Sterman's model, the low quality of the homework done reduces the grade of a student; however, in the educational system examined in this study, the low quality of the homework causes rework instead of lowering the score.

This article is organized as follows. In the next section, the literature is reviewed. Then, in the next section, the dynamic structure is described, and finally, results are presented.

Literature Review

A literature review has been done from two different angles: (1) models that have studied the dynamics of different educational systems with SD (2) models related to workload and burnout. The reason for reviewing workload and burnout literature is that, as you will see later, this is an essential part of our model. From the first angle, Kennedy (Kennedy 2008, 2011) classified the SD models of educational policy issues and educational pedagogic issues. According to these Kennedy’s articles and further search on google scholar and the bibliography section on the system dynamics society website[1], there is no research in this regard.

However, there are already quite broad studies on the topic of workload and burnout. For instance, Larsen (1969) builds a model to evaluate Managerial Strategies for Dealing with Work pressure in a Project-Oriented Environment. Homer (1985) examines the dynamics of “worker burnout”, the process in which a hard-working individual becomes increasingly exhausted, frustrated, and unproductive. Levine et al.’s (1985) model encompasses the literature on burnout and belongs to a general class of stress and motivational models that describe alcoholism and sexual harassment problems in the workplace, etc. Ogunlana, Lim, & Saeed (1995) attempt to understand the current practices and issues in design projects. A system dynamics model was developed to manage the detailed design process in a civil engineering project. The model took an integrative

[1] https://systemdynamics.org/bibliography/

approach, consisting of four interrelated subsystems: human resources, design production, controlling, and planning. Oliva (2001) explores how service organizations respond to change in work pressure, why they respond the way they do, and what managers can do about it. Holmström & Elf (2004) explore staff retention and job satisfaction at a maternity department, which was in an unfavorable spiral of attrition after an expansion period. They integrate factors of attrition and hiring rates, workload, and qualitative contents of the work. Bayer et al. (2004, 2005, 2006) model the fluctuating workload. Wiik et al. (2009a, 2009b) investigate the chronic problems of Computer Security Incident Response Teams (CSIRTs): workload, quality of service, and sustaining their constituency. Morrison & Rudolph (2011) present a model of how a build-up of interruptions can shift the dynamics of the emergency department (ED) from an adaptive, self-regulating system into a fragile, crisis-prone one. Lopez & Zuniga (2013) consider agent learning, resource utilization, human agent expectations, and target workload and performance goals. The article explores these issues in the context of a case study of a large high contact service operation. Lopez (2015) examines the effects of organizational responses to work pressure when capacity is managed through active and aggressive use of temporary employment. In Deuten (2017), the impact of work pressure on nurses' well-being and patient satisfaction is modeled. Rahmandad & Reopening (2015) model the "capability erosion dynamics". They study two software development organizations that experienced diverging capability trajectories despite similar organizational and technological settings to understand erosion. Building a simulation-based theory identifies the adaptation trap, a mechanism through which managerial learning can lead to capability erosion.

Model Description/ Model Structure

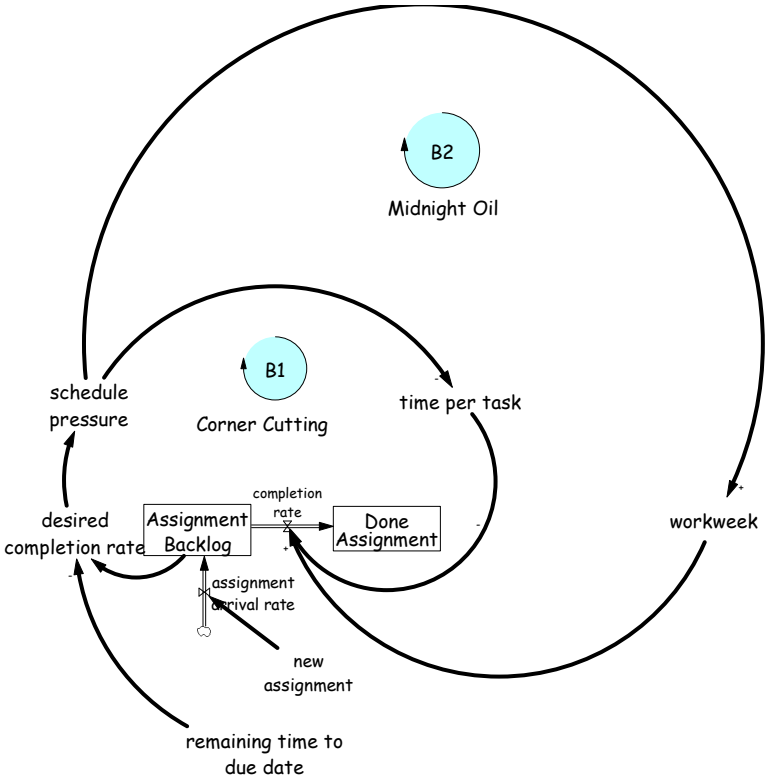

Figure 1: Corner Cutting & Midnight Oil loops

As shown in Figure (1), students are given new homework each week, accumulating in "Assignment Block" stock. Depending on how much time is spent on each exercise ("time per task") and total time spent on homework each week ("workweek"), homework is done, exits the assignment block, and goes to the "Done Assignments" stock. Both "time per task" and "workweek" depend on the volume of workload and time remaining to the due date, or in a word they depend on "schedule pressure"; the more schedule pressure, the more time per week (workweek) students have to allocate to clear their desktops. Also, schedule pressure can make students spend less time on each task. These relationships create two negative loops of "Corner Cutting" and "Midnight Oil":

- ***B1- Corner Cutting***: Assignment Backlog↑ ⇨ schedule pressure ↑ ⇨ time per task↓ ⇨ completion rate↑ ⇨ Assignment Backlog↓
- ***B2- Midnight Oil***: Assignment Backlog↑ ⇨ schedule pressure ↑ ⇨ workweek↑ ⇨ completion rate↑ ⇨ Assignment Backlog↓

Nevertheless, an increase in "workweek" and a reduction in "time per task" both have their consequences. On the one hand, as shown in Figure (2), reducing the time per task reduces homework quality, increasing the percentage of rejected assignments that should be redone. It creates a positive loop of "Rework" as follows:

- ***R1- Rework***: Assignment Backlog↑ ⇨ schedule pressure ↑ ⇨ time per task↓ ⇨ error rate↑ ⇨ Assignment Backlog↑

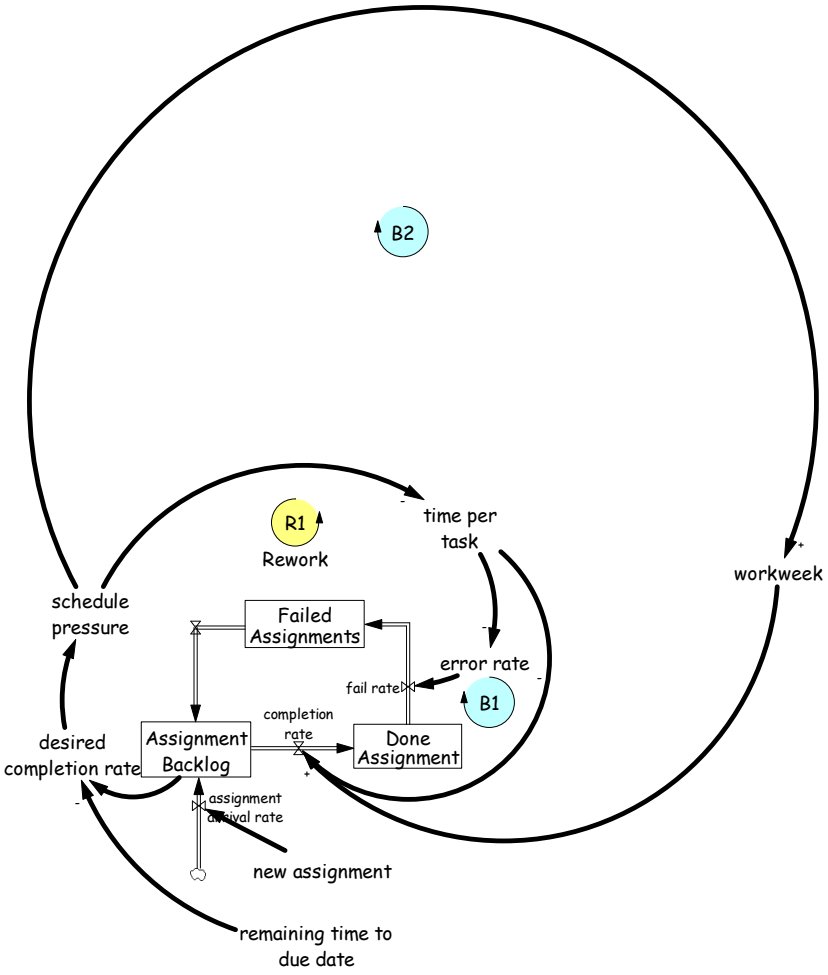

Figure 2: Rework Loop

On the other hand, an increase in "workweek" reduces "free time." Obviously, when students have less "free time," they will have less time to sleep, prepare healthy food, have fun, exercise, go to parties, communicate with others, etc. These activities are aggregated into an abstract variable name "health investment," and the time spend for them is "time for health investment." Enough "Time for health investment" is essential not only for students' physical health but for their mental health. Sufficient "time for health investment" is necessary for students to release their accumulated mental pressures (in "Mental Pressure" stock) stemming from "schedule pressure" and having "conflict" with others (namely, friends, classmates, family members, professors, and so on). So, cut in "time for health investment" can increase "mental pressure." "Mental Pressure," in turn, can increase the "stress level" students experience; that is, the more mental pressure, the more they feel stressed out. Of course, the "stress level" not only depends on "mental pressure," but it is affected by the "Tolerance Capacity"; people who have less "tolerance capacity" experience more stress level comparing those who have more "tolerance capacity" under the same pressure.

Rising stress levels can affect students' performance in five ways: (1) It can make a person nervous and aggressive, causing friction and conflict with others (2) it can reduce concentration, so the student will need more time to do their assignments (3) it can reduce concentration which can increase the rate of errors in homework (4) High stress can lead to illnesses such as migraines, nerve headaches, stomach aches, etc., so the person will have to spend some time in bed sick (5) high stress level can cause mental exhaustion, inclining the students to avoid doing school work and to do somethings that make them a little relax. These five effects add six loops (five positive loops and one negative loop) to the system (Figure 3):

- *R2- Conflict*: mental pressure↑ ⇨ stress level↑ ⇨ conflict↑ ⇨ mental pressure↑
- *R3- Concentration1*: mental pressure↑ ⇨ stress level↑ ⇨ concentration↓ ⇨ time per task↑ ⇨ completion rate↓ ⇨ assignment backlog↑ ⇨ schedule pressure↑ ⇨ mental pressure↑
- *R4- Concentration2*: mental pressure↑ ⇨ stress level↑ ⇨ concentration↓ ⇨ error rate↑ ⇨ failed assignments↑ ⇨ assignment backlog↑ ⇨ schedule pressure↑ ⇨ mental pressure↑
- *R5- Illness:* mental pressure↑ ⇨ stress level↑ ⇨ sick time↑ ⇨ remaining time to due date↓ ⇨ schedule pressure↑ ⇨ mental pressure↑
- *R6- Mental Exhaustion*: mental pressure↑ ⇨ stress level↑ ⇨ mental exhaustion↑ ⇨ workweek↓ ⇨ completion rate↓ ⇨ assignment backlog↑ ⇨ schedule pressure↑ ⇨ mental pressure↑
- *B3- Health Investment Time*: mental pressure↑ ⇨ stress level↑ ⇨ mental exhaustion↑ ⇨ workweek↓ ⇨ free time↑ ⇨ time for health investment↑ ⇨ mental pressure↓

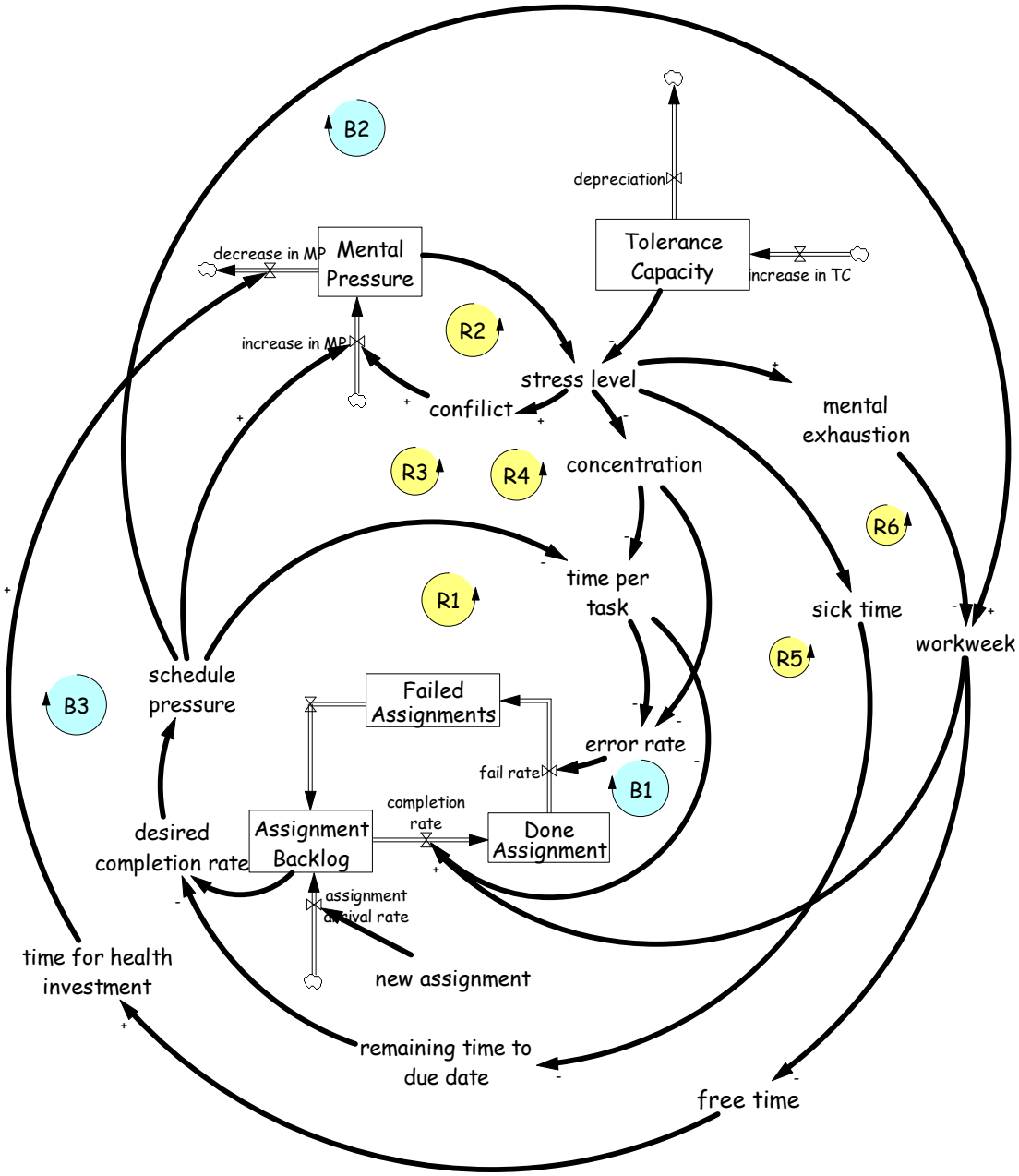

Figure 3

The negative loop of B3 (health investment) creates a mechanism similar to the "burden the shift" archetype. When a student spends more time relaxing, they can decrease their stress level in the short term, but in the long term, it leads to accumulation of assignments, increasing schedule pressure, and mental pressure. Another critical point is that people's mental capacity is not constant, and it can be eroded by mental pressure bit by bit over time. This adds two other loops (a positive loop and a negative loop) to the model (Figure 4):

- *R7- carrying capacity erosion*: mental pressure↑ ⇨ depreciation↑ ⇨ Tolerance Capacity (Resilience)↓ ⇨ stress level↑ ⇨ conflict↑, time per task↑, concentration↓, sick time↑, workweek↓ ⇨ ⇨ schedule pressure↑ ⇨ mental pressure↑
- *B4- carrying capacity erosion*: mental pressure↑ ⇨ Tolerance Capacity↓ ⇨ stress level↑ ⇨ mental exhaustion ↑ ⇨ workweek↓ ⇨ free time↑ ⇨ time for health investment↑ ⇨ mental pressure↓

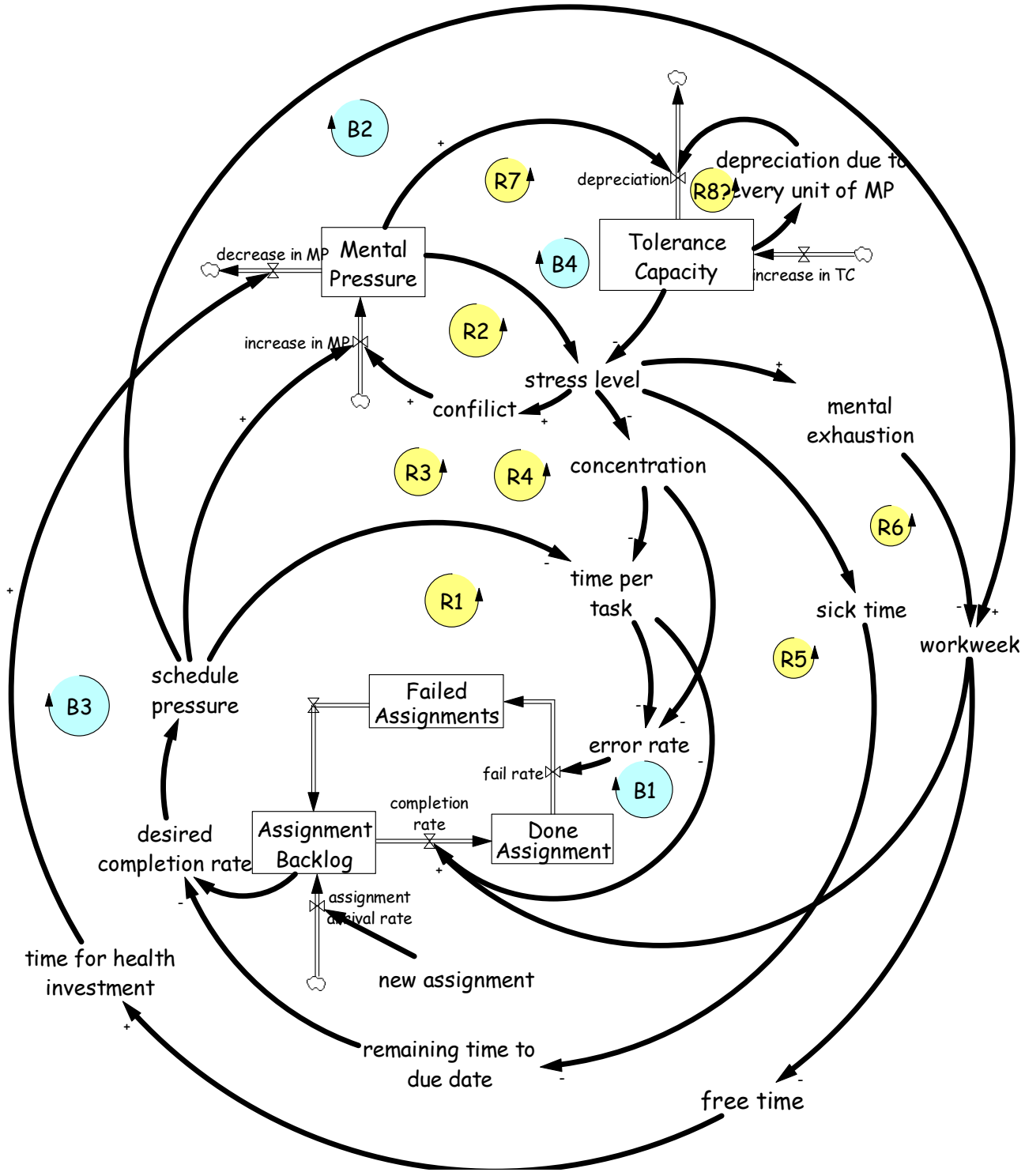

Figure 4

The noticeable point in this model is that if we distill the above model (as shown in Figure 5), we can see that there is an "overshoot and collapse structure" embedded in the model which can generate a behavior like what is shown in Figure 6 (Sterman, 2000, P.123)

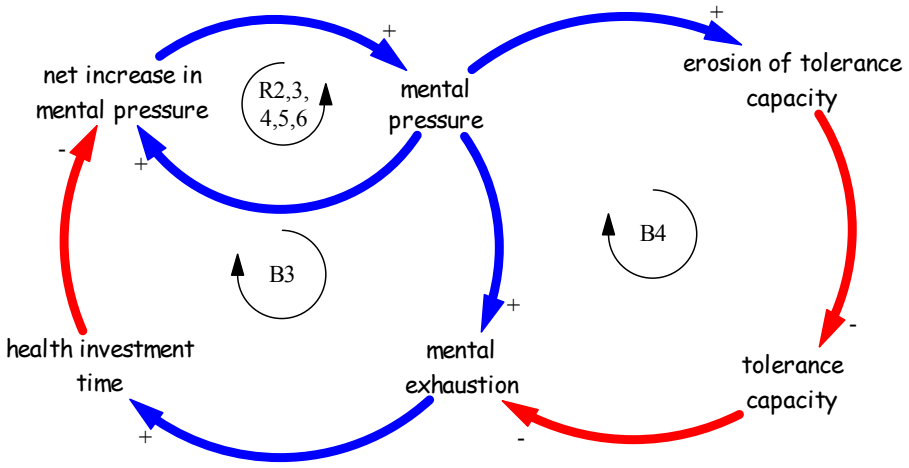

Figure 5: overshoot and collapse structure

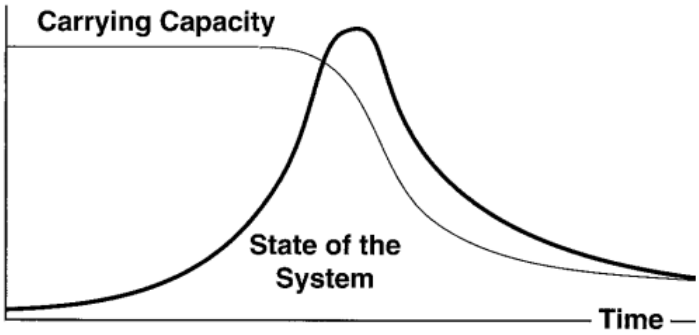

Figure 6: overshoot and collapse behavior

Results

Probably the most effective first step in attempting to fight a complex problem is to understand its dynamic source. The result of this study is a causal loop diagram (consisting of 11 feedback loops) which shows how a strict standard for homework acceptability can increase students' workload and stress so much that it can harm their productivity and mental health. We are hopeful that this paper can be insightful for education policy-makers. Future research is needed to expand upon this initial model, and quantitative extensions may result in a better understanding. A quantitative model can help us evaluate how much different policies can be

effective; policies like restructuring the education system and making students more resilient. It may also be helpful for students to find a solution to manage their time in a way to avoid the potential traps in this education system.

Received Comments

Reviewer 1: Great paper. It identifies a unique problem on which has not been explored much within SD. The archetype used to explore the problem is well defined and modeled. (Only to Author): Thank you for the paper. It was fantastic. It would be good to expand on the results and identify what the SD research is indicating in this regard. What could be potential policy implications for implementing this education system across larger education systems? What would be the impact on the educators- since that too is a limited stock.
Reviewer 2: As an ambitious doctoral student currently 'burning the midnight oil,' so to speak, I experienced catharsis in reviewing this paper and think it has much potential for adding to the literature and possibly transforming education if disseminated properly. I much prefer a system that celebrates and encourages learning rather than implicitly requiring students to arrive on the first day of a new course with a mastery of the course content and being punished if they do not have that requisite mastery. This paper presents CLDs of the negative consequences of an educational system in which assignments are graded in comparison to a system in which assignments are reviewed for a minimum level of competence and students are asked to re-do the assignment if it is not up to standards. The authors depict pluralistic causal factors within the system and 11 feedback loops. They argue that more learning and better health/mental health outcomes for students would occur within the model that is less punitive for learning. The authors do not state what stage of education this is, though they mention professors, so it could be aimed at higher education. It would benefit the authors to predict and refute opposing viewpoints, e.g., "What about grade inflation and maintaining the rigor of our prestigious program?" (Only to Author): 1. Could use more recent references 2. Some references not consistently formatted 3. Suggest labeling your reinforcing and balancing loops with a name of what is happening 4. A transition between the literature review and first model would be useful. 5. Are there necessary additional factors in the first model? Estimated vs. observed time to complete task? etc.? 6. "Workweek" isn't clear to me 7. What about adding "learning", "mastery of content", and/or "grades" to Figure 1 and Figure 2? 8. Do the names of these systems of education/homework assignment and grading have names that are referred to in the literature? 9. What educational level/age group do you have in mind here? 10. I appreciate your consistent style with these hybrid models, the font, the capitalization, etc.

11. The B2 in Figure 2 is quite a bit loopier than in Figure 1. Is that intentional?
12. The literature review was effective and demonstrated an excellent handle on the literature.
13. Idea: what about a changing of the set point "tolerance capacity" over time through accumulation of backlogged assignments, more stress, additional exogenous stress experienced that limits ability to complete work, or getting negative feedback from others on the timing or quality of the work?
14. Thank you for explaining the components of each of the feedback loops and what occurs in them.
15. You say, "Education experts have always sought to design appropriate educational systems to maximize learning productivity and minimize the pressure students may experience." What about hidden curricula and instances where the system is purposefully made more difficult than merely learning the course content?

Reviewer 3: The paper could be best described as a "Fun and casual" application of SD in a potentially important problem. The paper traces the dynamic source of a problem related to weekly non-graded assignments and associated rework and stress for students. Arguably, the practice is commonplace in the world. While the paper does a good job developing a CLD using the existing common archetypes, however, the paper lacks rigor associated with a typical academic paper expected to be presented at the SD conference. It needs a major overhaul for it to be considered. The problem's relevance has not been explored; the literature review is loosely connected to the overall context presented. No support is provided for any cause-effect relationship, which could still be understood if there would have been a substantial contribution to theory development. Further, there are no discussions, implications, limitations etc. The model description provided has some merit for making the SD beginners start appreciating complexity in seemingly simple behavior.

(Only to Author): Based on the impressive narratives of various loops listed in the paper, it is clear that authors thoroughly understand the principles of SD and have a strong familiarity with its concepts. Hence, I also strongly believe that it was not the authors' intention to present the paper following rigorous academic practices. If needed, the authors would surely be able to do so. Hence, my comments are related to some of the model assumptions which need to be considered, if at all, this model is further developed for practical purposes.

1. Whether the students are really facing such an issue related to stress, and that too because of such seemingly benign practices, is a claim that needs to be sufficiently justified.
2. The corner-cutting is not the only possibility of the loop description B1. The Yerkes-Dodson law could also be at play. The Corner-cutting loop blames the student excessively.
3. On the flip side, I was surprised to see no variables related to the effect on student's learning of specific concepts, or retain concepts later etc. I believe many teachers end up following such practices because there is a strong belief that students would be able to retain that knowledge better if they write it again and again. Without consideration of such effects, the model does not present a full picture for the policy-makers.
4. From a personal example, such practices in the school are also associated with a periodic graded evaluation of the average homework performance. For example, in our school, twice in an academic year, the teacher would evaluate the average quality of the homework submission in the past 6 months, and once graded, the remaining backlog automatically gets eliminated, as the student no longer have to worry about the backlogs for which he/she received a rather poor grade. The point is that the paper, in its current form, presents a rather skewed picture. Still, without a proper justification of the problem's relevance, it is difficult to visualize any practical application of the model.

A fun read, nevertheless.

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