Loops All the Way Down – How Incorporating Feedback Loops into Our Teaching Perspective Can Elevate Math Pedagogy

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ABSTRACT

This paper analyzes secondary math student behavioral patterns from the lens of a systems theorist. Using the concept of feedback loops, we can see why some students fall into detrimental patterns that lead to low achievement in mathematics. Also, the author will relate his experience with Thinking Classroom Methodology, work by the professor Peter Liljedahl, and how it improves math pedagogy also through the lens of feedback loops.

Keywords: Secondary math education, self-regulated learning (srl), feedback loops, thinking classroom, vertical non-permanent surfaces (vnps)

INTRODUCTION

Students are always learning, but not always what we expect them to learn.

Primum non nocere – Hippocratic Oath (First do no harm!)

What started a journey that led to this article was a series of conversations with a colleague while teaching secondary students STEM subjects. During those conversations, we pondered on the fact that some students acquired a deep dislike for math and science subjects even before they have reached our classrooms. Could it be that schooling could be harmful? Educators don't take the Hippocratic Oath like medical doctors, but maybe educators need a similar code of ethics. This missing code of ethics should state that we fail as educators when students leave school with a dislike for learning. In a review of the literature surrounding motivation patterns in mathematics, Middleton [1] stated that "[it is] particularly distressing, that students learn to dislike mathematics and that this dislike becomes an integral part of their mathematical self-concept."

The issue of reduced and meagre motivation of students in STEM is a deep and complex issue that this article only scratches the surface. In the significant paper from the Chicago Consortium [2], have put together a framework with academic mindsets as the top category of non-cognitive factors that lead to student achievement. The work of Dweck, Boaler, Duckworth and many others have elevated the importance of non-cognitive factors like grit, motivation, and mindset in the minds of educators. This paper examines a small piece of the puzzle, by looking at the issue from a systems perspective. Two common behavioral patterns in the mathematics classroom will be examined using a concept taken from Complex Systems, namely feedback loops. In the first behavioral pattern, the feedback loop will be used to postulate how students become disengaged in their own learning process. The second behavioral pattern will examine the opposite of lowly motivated students, which are self-regulated learners. From examining those two patterns, the role of teachers as a causal agent in dampening student motivation can be theorized. Finally, some ideas will be suggested to improve the feedback loop patterns, with a focus on the exciting and promising impact of using Thinking Classrooms methodology created by Liljedahl.

RESULTS AND DISCUSSION

Our World is Built on Feedback Loops

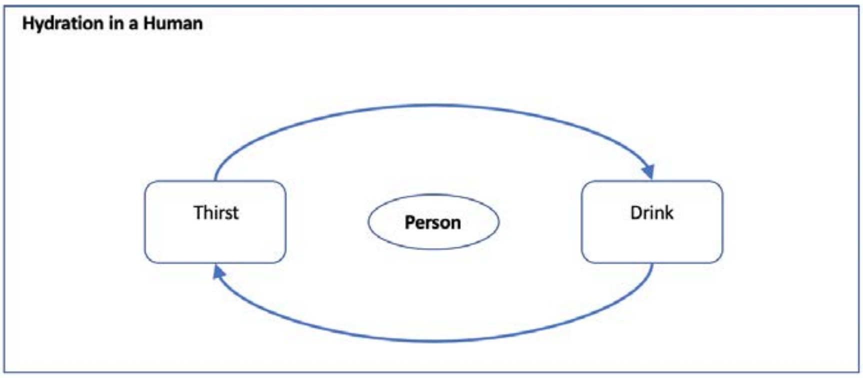

Figure 1. A simplified diagram of a feedback loop that shows body water homeostasis

What exactly is a feedback loop? Let's start with a system. A system is "an interconnected set of elements that is coherently organized in a way that achieves something" [3]. Almost everything can be described as a system, ranging from very complex with many parts, like governments, ecosystems, or circulatory systems in an organism, or very simple with only a few parts, like a person, his thirst, and a glass of water. Systems have three major components which are the elements, interconnectedness and a function or purpose. If we look at how systems are interconnected, the connections between the elements will eventually form loops. One way to see feedback loops is through a chain of cause and effects. Here's an example of a balanced feedback loop. See Figure 1. Over time, as a person loses water, his thirst increases. This causes him to seek out drinks. As he imbibes some drinks, his thirst is satiated. The body is the system and homeostasis is its goal. Without feedback loops, the body cannot operate. Feedback loops could also be reinforcing or dampening. For a reinforcing feedback loop, think of a microphone pointed to a speaker. Ouch! For a dampening loop, think of what happens when a company has a culture of shooting the messenger. Everyone is afraid to speak up. See [3] for a good primer on systems.

Feedback loops are neither good nor bad, but are powerful in ways that can shape institutional culture. It can lead to ingrained beliefs and habits, and sometimes feedback loops make culture and habits resistant to change. Before my discussion of the two common patterns that are observed in the context of a math classroom, a short digression on the use of the term feedback in the education literature.

The term feedback, as espoused in educational research and literature, is commonly acknowledged to be essential to learning. Hattie [4] has stated in his meta-study of what works in education that "feedback is a common feature of successful teaching" and that feedback can be "…provided in many ways" [4] [4]. In other literature, feedback is synonymous with formative assessment [5], or comparing the effects of grades versus written comments [6], or feedback is described in terms of what teachers can do [7]. In most cases, the term feedback is used in a narrow way that doesn't take into account the holistic nature of feedback loops. Another problem is that the notion that feedback is something done to students. Obviously, many books and articles are written for teachers, so notions of feedback are framed from the teacher's perspective and the advice prescribes 'teacher moves' in the classroom. See Hattie [8] for a good overview of feedback as used in the math classroom.

Can this narrow view of feedback be camouflaging a pattern of feedback that is demotivating students?

The Case of the in-Curious Learner

As educators, we've all encountered a special species of students that seem to proliferate as fast as weeds. Students in this archetype have some of these characteristics. They are solely interested in the grade and not any learning that is attached to that grade. If an assignment is not graded, they will not do it. They choose to copy their friends' work instead of doing the work themselves. When they are caught cheating on a test, they are mad at the teacher for ruining their reputation as a student. If they are honest, when you suggest them to do extra practice to improve their skills, they scoff and say sarcastically, “Like I would do math in my free time.”

Is there anything wrong with these students? Some educators might be inclined to blame the students, but can you see yourself in the students’ shoes? Could it be that the school systems have trained them to act in that way? Here is an example of a typical pattern in math class. See Figure 2.

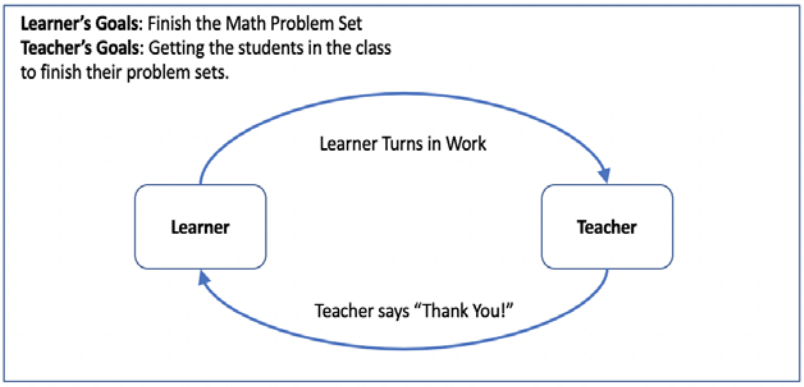

Figure 2. A typical feedback loop that students go through on a regular basis

This pattern might be very common and maybe teachers who are in this pattern don’t sense the danger. From the perspective of the learner, it also looks perfectly fine. The learner is perfectly happy. By completing the loop and receiving closure by the teacher, the student feels finished, done, satisfied. That’s how the psychology of open loops work in the mind. Open loops, which are processes not yet completed, cause tension in the mind of a person; our natural tendency is to want to close the loop. This is well known by entertainers and storytellers. That’s why writers use cliffhangers to keep the audience coming back for the next installment. That’s why hypnotists use open loops to embed suggestions. That’s why comedians use callbacks to enhance the laughter. That’s why the person with OCD, must check all the locks before he goes to sleep.

Therefore, it feels very natural to be in a pattern like Figure 2. The student feels accomplished by completing an assignment and turning it in, hearing the teacher acknowledge their work, and also the teacher feels accomplished that the students are working. However, this pattern that gets repeated over and over again, is training the student that his goal is to turn something in, his goal is to satisfy the teacher. What’s missing is the learning. The goal of learning has been replaced by the goal of finishing. What’s missing is the quality of the work. Of course the teacher might ask for revisions the next day, but in the mind of the student, it’s over. Another important problem with this loop is that the student doesn’t have full agency over their work. It becomes the teacher’s prerogative whether to accept the student’s work as acceptable. Rather than guiding students to because more skillful mathematicians, teachers are taking away students’ capacity to determine the value in their own work. With math, students often turn in work with easily identifiable errors that could be fixed with simple checking, or they have the answer key in the back of a textbook that they could use to verify their work. So, over the years as this pattern in Figure 2 repeats itself this lack of learning will catch up to the student when they move on to a higher level math class. As this pattern continues over the years, a dependency on teachers leads to helplessness, lack of confidence and uneasiness. Students enjoyment and interest in a topic comes from their belief in their ability to learn [1]. By taking away this ability, no wonder so many students develop an intense dislike of mathematics. The end result is the in-curious learner.

Self-Regulated Learners, the Holy Grail of Students

For more than thirty year, researchers in the field of educational psychology, have studied students who they call self-regulated learners [9]. Self-regulated learners ultimately have control over their own learning. They set their own goals and determine their strategies and methods to reach those goals. They seek feedback to understand if they are successful. Finally they reflect on what they did. A few different models of Self-Regulated Learning (SRL) exist, but they all clearly demonstrate: that learners guided by strong motivation strategies and beliefs, that learners who take control of their learning and behavior, and that learners who plan and reflect, are very successful in the academic world [10]. As educators, or to anyone who has spent time trying to motivate young students, the success of self-regulated learners seems like an obvious conclusion. Let's examine the feedback loop of a self-regulated mathematics student. See figure 3.

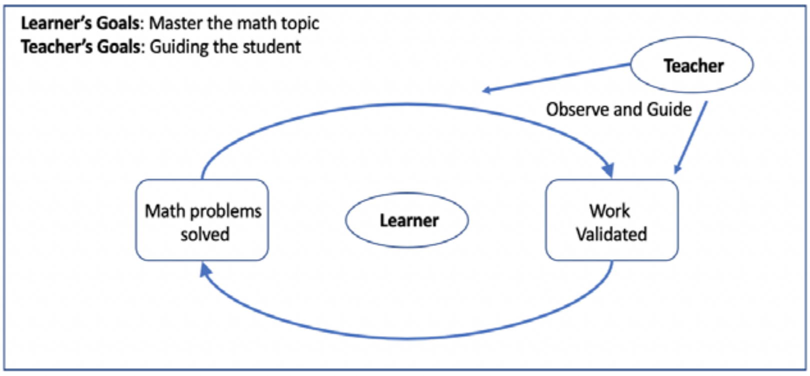

Figure 3. The learner at the center of her learning.

A student at the center of their own learning becomes a competent student; the student has authority, taking advantage of different methods of validating their own work while the teacher is on the outside guiding and observing. Some examples are students that takes out their calculators to check their work after their finished, or students that take advantage of the answers listed in the back of a textbook, or students discuss their work with a friend, or the student that uses estimation and other strategies to verify their own work. Also the model in Figure 3 can be used to analyze a student's behavioral patterns on a range of different time resolutions, whether working to excel in class, prepare for the AP test which has a time scale of months, or we can zoom in to a calculation that a student can verify with a calculator that happens over the course of a minute. If we continue to examine a self-regulated mathematics student working through problem after problem in the course of a day, every successful loop becomes reinforcing, building confidence, skill and enjoyment with math. Comparing this to the in-curious learner, every problem leads in the other direction where every loop is taking away from the students' confidence and enjoyment.

7+1 Suggestions for Teachers

Here are some ideas to try to move the model of learning in our classrooms to one of independence and self-regulation. Any lack of credit given to the sources is solely the author's defect.

1. Plan for activities that students can verify their own answers without the teacher. One example is Marcy Cook Tile Math. The students have numbered tiles from 0-9 that they use on a worksheet, where each worksheet is designed to use each tile once. That way it's easy for the students to recognize when they are correct and when they have made a mistake.

2. For students that forget to check and verify their work before they turn it in. Place an 'X' on the ground that students pass by on their way to turn in a paper. This 'X' is used as a visual cue for students to check their work. Teach the students that when they should stop on the 'X' before they turn in their papers, and then ask themselves if they have checked all their work.

3. Create incentives for students to check their work, or disincentives to turn in work quickly. Example of an incentive, on a math test, include a box where they get a bonus point for checking their answers. Example of a disincentive, in a English class, students who turn in their work (writing a paragraph) must rewrite the whole paragraph if they forget their punctuation.

4. Always convey the message that it's not about the answer, but the logic of getting to the answer. For example, James Tanton, a mathematician, shared that he supplied answers, even on quizzes to bring home the message that it's not about getting an answer.

5. While we are interacting with students and they often ask if their answer is correct, we can turn the question back and ask them how they can know if the answer is correct. Show the students how to

verify, how to check with a different method, and how to use estimation to gauge if the answer makes sense.

6. The author has only tried this with his own daughter, not with any student in class. It seems to have worked. When the daughter asked for help on a math question, the author waved his hands over her head and hummed off-key saying that he transfers energy into her brain. It seems to have worked. The daughter asks for help on her math homework maybe once every few years.

7. Incorporate a few ideas from Use Thinking Classrooms, developed by Professor Liljedahl. This will be elaborated in the next section.

8. Ask yourself, are you having fun?

What is Special about Thinking Classrooms

There's a similar journey that some math educators go on. The first is the thought, "Hey, I'm pretty good at math, teaching math must not be too hard." Then that initial optimism is shattered as they realize that it's much harder to teach mathematics than they thought. The next stage of the journey involves going on the path of self-improvement, and learning from our elders. Along this path, we come across many different schools of thought, many different methodologies. Some of these may be familiar to you: Japanese Lesson Study, Five Practices, Notice/Wonder, Singapore Math, 3 Act Math, and many more. What is rare is a methodology with results that are immediately noticeable.

Over more than a decade, Professor Liljedahl has been studying the factors that go into a classroom that he defines as thinking versus non-thinking [11]. Classrooms where students are engaged, working together, and learning. Through his research, he has put together a prescriptive framework of fourteen different methods that push a class towards thinking versus non-thinking. In this article, only one method of the fourteen, using Vertical Non-Permanent Surfaces (VNPS) will be analyzed by a feedback loop.

Using Vertical Non-Permanent Surfaces (VNPS) means to have the students work standing up on whiteboards, blackboards, windows, or whatever surfaces that are erasable [12]. The benefits are: students are more active while standing, and students are more willing to take risks with erasable surfaces. The most important benefit, in the perspective of the author, is that it helps the teacher in monitoring the students. Delays have a great impact on feedback loops. When students, mostly in-curious, are working in a typical classroom on horizontal desks, the delay is longer because the teacher must work much harder to monitor what the students work. Errors in their work, and errors in their logic can proliferate until a typical cycle of collecting work, correcting and returning to students. Even with an exit ticket, the teacher can only notice and respond during the next class. Also if we wait to respond in another class, as we have discussed before, students have already moved on because in his mind, once his work is turned in, he is done. On the other hand, monitoring students around a classroom working on VNPS, is quick, immediate and easy. The teacher can quickly glance across the room and see who is engaged and who is not. It is much harder to hide. The teacher can also quickly see how the students are tackling the problem and what sort of obstacles they are having. An excellent practice for math teachers is to anticipate errors that students might make, but if a teacher is new to a school district or new to a grade level, sometimes anticipating is extremely hard. This helps teachers monitor for student misconceptions that the teacher didn't anticipate.

CONCLUSIONS

There are three goals of this paper. One is to raise awareness that school systems and teachers even with good intentions could be harming students, evidence can be seen when students learn to dislike a subject. The second goal is to encourage more research in what factors create more in-curious learners so we know what we need to stop and more research on how to move students from being in-curious to self-regulated. Finally, the last goal is to endorse and spread the news of Professor Liljedahl's work in Thinking Classrooms.

Let's take a step back and look at the structures in place in our classrooms and schools, and always be asking if there's a better way.

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