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Monitoring students' growth using system dynamics

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by

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ABSTRACT

Researchers have long been trying to analyze the problems associated with the teaching processes at universities [6] [7]. Most such research is focused on trying to understand the problems associated with teaching and analyzing the impacts of these problems on student learning. However, little work has been done in modelling the teaching/learning process to understand how different problems affect the knowledge gained by the students. The problems may impact students' motivational development, teachers' teaching interest or even students' learning process. In this paper, we propose a model that we use to simulate the existing teaching process at universities, using system dynamics [12]. We demonstrate that an analysis of different parameters extracted from academic, personal and motivational fronts using system dynamics can provide a clear picture of the influence of real life events on students' performance. System dynamics helped us to monitor the students' growth over the duration of a course, guiding us to analyze the root cause of the problems. As a result, system dynamics helps to provide a solution for efficiently dealing with students' difficulties. The results show various trends among teachers' enthusiasm, students' enthusiasm, students' knowledge, test anxiety, teaching quality and students' performance over time. For example, teachers' enthusiasm reduces by approximately 4% when teachers' mental stress increases by 10

CHAPTER 1

INTRODUCTION

Imparting knowledge is a crucial process aimed at helping students to grow in a classroom. This process contends with various factors, such as teaching quality, teachers' enthusiasm, personal issues, students' enthusiasm, and test anxiety. Each of these has some form of impact on the knowledge gained by the students over the course. Moreover, the interaction among these factors makes the analysis of students' learning rates very challenging.

1.1. **Existing teaching approaches**

In general, American universities follow a teaching approach where the teachers provide a defined course syllabus [1] to the students that describes course components, course goals, student learning outcomes, textbooks, assignments and tests, course schedule and the grading system. The method adopted for imparting knowledge is usually in the form of lectures, where the teacher stands in front of the entire class and conducts the session using blackboard or projector. Students are encouraged to participate in the class, which helps the teacher understand students' learning pace. Most courses involve a series of assignment submissions with one final exam and one or two midterm tests (the number of tests may vary depending on the teachers' requirement). Course instructors and teaching assistants conduct office hours where students come and discuss their problems personally with the teachers. Sometimes, teachers help the students outside their regular office hours.

1.2. **Psychological factors involved**

Over the years, researchers studied how instructors' attitude and behavior in the class affect student learning [2]. According to their theories, factors such as teachers' enthusiasm have a significant impact on the student motivation. Similarly, there are many other psychological factors affecting learning that are associated with the teachers and the students. Such factors change dynamically over the course of the teaching and learning process. Students' enthusiasm also depends on the teaching quality, how much interest students possess in their academic field and how interesting they find the topic taught in the class. Students may also suffer from mental, physical and personal problems that affect their motivation level [3]. Their perspective towards life also affects how they face daily challenges such as low scores on tests. Test anxiety is prevalent among many students who want to avoid getting low scores because of family pressures, high self-esteem and social reputation.

Similarly, the teachers' domain of interest also affects the teaching quality. Teachers may also have personal or family issues that may affect their enthusiasm. Moreover, some teachers get into the teaching domain as part of voluntary participation, whereas other teachers pursue it as a profession in order to earn a living. Thus, a teacher who is satisfied with his or her job paycheck and has few personal issues will be able to teach effectively. However, an unhappy teacher is unlikely to demonstrate effective teaching skills in the classrooms.

Researchers also observed a reciprocal effect of students' motivation on the teachers' enthusiasm, thereby causing a feedback effect [4]. In a class environment there are many feedback loops among various parameters that impact the knowledge gained by the students over a course. Today's biggest challenge is to analyze the dynamic behavior of all the parameters together, which involves many feedback loops and time delays. This type of analysis is very complex and the quantification of impact by various parameters on students' learning rate is very difficult and cumbersome.

1.3. **Why choose system dynamics?**

System dynamics (SD) is a methodology and mathematical modelling technique for framing, understanding and discussing complex systems, process issues and problems. We chose system dynamics to model the existing teaching process at universities because SD allows one to analyze the dynamic behavior of a system by considering all the positive and the negative feedbacks and time delays. The SD model of a process allows one to structure the interactions and control defined in the model [5].

With SD, we were able to simulate the teaching process efficiently and we quantified the impacts of different parameters on the student learning rate. With the help of modelling equations we were able to calculate the amount of knowledge gained by the students in a programming course. Also, we performed trend analysis between the student and the teacher behaviors on various personal and academic fronts. Results from these analyses helped us to predict the students' test performance for the entire class. Moreover, we were able to provide suggestions to the instructors for improving the overall teaching process.

1.4. **Related work**

Several researchers have performed analyses of student learning using parameters such as teachers' enthusiasm, student motivation, teaching patterns, course assessment and personality characteristics. Bettencourt, Gillet, Gall and Hull focused their research on the examination of effects of teacher enthusiasm on student attention or student engagement [6]. Their results supported a hypothesis about the presence of high student attention in the lectures with high teachers' enthusiasm. Richard M. Ryan and Edward L. Deci studied the relations between intrinsic and extrinsic motivation [7]. Their main concern was with "how teachers, parents and other socializers can lead students to internalize the responsibility and sense of value for extrinsic goals". At the end of their study, they concluded that social contextual conditions that support one's feelings of competence, autonomy, and relatedness are the basis for maintaining intrinsic motivation and becoming more self-determined with respect to extrinsic motivation.

A study by Andrea M. Wood examined the cognitive and affective mechanisms underlying the effects of teacher enthusiasm [8]. Her results suggested that teachers' enthusiasm has a direct impact on student motivation, attention and text memory. Moreover, she observed that teacher enthusiasm facilitates learning only when it strategically emphasizes important points in the lecture. Hembree integrated the results of 562 studies by meta-analysis to show the nature, effects and treatment of academic test anxiety [9]. According to his analysis, test anxiety cause poor performance and is also inversely related to students' self-esteem.

Michael Strong tackled the major issues surrounding teacher quality and effectiveness [10]. His book "The Highly Qualified Teacher", provides an overview of his research on teaching quality, where he introduces a new method for evaluating teachers based on extensive fieldwork in schools. Park, et al, conducted a study to identify the factors influencing academic stress in medical students and investigated the causal relationships among those variables with path analysis [11]. Their path analysis results indicated that stress, motivation, and academic performance formed a triangular feedback loop. Rohit Gujrati modelled the high quality distance education program at IIT Bombay using a System

Dynamics approach. His results helped him to make policy recommendations for refining the structure of the system [13].

Our work differs significantly from the above works. Besides studying the impact of different variables on each other separately, we have modelled all the above factors that impact the knowledge gained by the students in a single system dynamics model. We focus on simulating the real life environment and behaviors happening in a class. The model involves many feedback loops and time delays among different parameters, such as students' enthusiasm, teachers' enthusiasm, test anxiety, teaching quality, personal issues, and course complexity. To the best of our knowledge, there has not been any prior work that quantifies all the above mentioned factors and analyzes various feedback loops and time delays in a single simulation model. We think that our model is a better way to perform system analysis because while previous work has performed just the impact analysis on different parameters, our model provides quantified results for the student knowledge gained at the end of the course and also examine nonlinear behavior for many different relationships in a single model. We also examined the various problems that lead to lower test scores for the course. Our model will help the teachers predict the future impacts of their current decisions and shall help them to eradicate the root causes of problems by monitoring students' growth.

1.5. Research questions

In our research we discuss and try to answer the following.

RQ1. What strategies can improve the teaching process at universities?

RQ2. How much extra effort (in comparison to regular office hours) is required from the teachers and students to achieve the desired students' test performances?

RQ3. How well can we forecast students' test scores for the entire course duration using the system dynamics modelling technique?

RQ4. How do various parameters, such as teachers' enthusiasm, students' enthusiasm and teaching quality, impact the amount of knowledge gained by the students over the course?

1.6. **Hypotheses**

In our research we will try to verify the following hypotheses using data analysis.

H1. Teachers' enthusiasm has a significant impact on the learning interest of students in class.

H2. Students cannot completely remember what they learn over the course for a lifetime. The time to forget this knowledge will depend on the complexity of the course and the time put in by the students to practice the topics.

H3. Performance gap, the difference between students' desired grade and students' actual grade on exams, affects students' enthusiasm and builds test anxiety for students.

H4. Students' enthusiasm has a reciprocal effect on teachers' enthusiasm. For example, an increase in students' enthusiasm will increase teachers' enthusiasm.

H5. Performance gap can be reduced over time if students stay motivated and work with their teachers on their problems.

H6. Teaching quality and students' enthusiasm affects students' homework performance.

H7. Personal issues affect teachers' enthusiasm and students' enthusiasm.

H8. Course complexity does not impact students' performance for students who practice the

topics well and stay motivated.

Table 1.1 shows the relationships between various research questions and the hypotheses answering those questions.

Table 1.1: Relationship table between research questions and hypotheses

Research Question	Related Hypothesis
RQ1	H1, H5, H8
RQ2	H3, H5
RQ3	H1, H2, H4, H6, H7, H8
RQ4	H1, H3, H4, H5, H7, H8

For example, RQ1 talks about strategies to improve teaching process. This question can be answered using hypothesis H1, H5 and H8 that analyze impact of teachers' enthusiasm, performance gap and impact of course complexity. Using the results from these hypothesis, we can suggest some improvements.

CHAPTER 2

SYSTEM DYNAMICS BASICS

System dynamics (SD) models the dynamic complexity involved in a 'system'. According to Rohit Gujrati, a 'system' is a collection of parts that interact with each other in a way that displays the property of the whole structure. However, these properties are not evident from different parts constituting the system [13]. According to Sterman, "Our mental models are limited, internally inconsistent, and unreliable. Our ability to understand the unfolding impacts of our decisions is poor. We take actions that make sense from our short-term and parochial perspectives, but due to our imperfect appreciation of complexity, these decisions often return to hurt us in the long run."[14]. Properties that become evident only when the system is in place and operating are often called emergent properties; they result from interactions among the different components.

To overcome the problem of decision making associated with our mental models, we implemented the system dynamics modelling technique in our research. According to Sterman, "System dynamics is a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems. System dynamics is also a rigorous modelling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations."[12].

2.1. **System dynamics simulation**

System dynamics (SD) is a computer aided approach that uses simulations for analyzing complex systems. SD simulations are based on three principles: cause and effect, feedback and time delays. Cause and effect relationships help us to understand the impacts of different parameters on each other. When examining these cause and effect relationships in isolation, they are very easy to understand. However, when we combine many such cause and effect relationships together, we give rise to a complex system [15]. Feedback is the process where a parameter is influenced by itself and other parameters in the near future. These feedback loops form a very important aspect of SD modelling. We can categorize these feedback loops into negative and positive feedbacks loops. Time delays are an inherent part of all flows. For example, it may take time for a teacher or a student to react to a personal issue that will slowly impact their enthusiasm in the class. Such time delays can even make the system oscillate. There are two types of delays. According to Albin, "A material delay is a delay in a physical flow. In contrast, an information delay is a delay in perception."[1][16]. The delay between a change in the rate of teachers' personal issues and our belief about the likely future teachers' enthusiasm value is an example of information delay. Delays and the feedback structure of the system cause nonlinear behavior.

Advantages of simulation-

Some of the advantages of model simulation are as follows [15].

- Simulation helps to visualize the model, which increases the understanding of the system's behavior.
- Simulations allows one to see emergent properties that may not appear in static analysis. This property can also be used for training purposes.

Disadvantages of simulation-

- The simulation results may not be 100% correct. An unexpected scenario can completely alter the system results.

[1]Information delay may have different meanings in different domains. We may also define it as the delay in the information transfer from one place to another

- Validation of simulation models is very challenging. We require a large data set to test thoroughly different environments, different input sets and different user types.

2.2. **Graphical representation of system dynamics models**

Let us look at the graphical representations of SD models that help us to analyze the feedback structures of various systems.

2.2.1. **Causal loop diagram (CLD)**

CLD is used to illustrate the cause and effect relationships between various parameters. These diagrams use arrows that help in understanding the direction of impact. The arrows can carry a positive sign or a negative sign. A positive sign signifies a direct proportionality between two parameters. For example, a positive arrow sign going from "Birth" to "Population" indicates an increase in the "Births" parameter causes an increase in the "Population" parameter. In contrast, a negative sign indicates an inverse proportionality relationship, where an increase in the value of one parameter decreases the value of the other parameter.

Feedback loops are present in the form of cycles in the causal loop diagrams. We illustrate the properties of CLDs in Figures 2.1-2.4, taken from [13]. There are mainly two types of feedback loops that depend on the overall sign of a loop.

- Positive (Reinforcing) Feedback loop- This loop is represented by a positive sign in the center of the feedback loop. A positive loop contains an even number of negative causal links. This loop illustrates an exponential behavior. Figure 2.1 shows a reinforcing feedback loop, where the values of "Adults" and "Children" parameters are continuously increasing, resulting in an exponential graph [13].

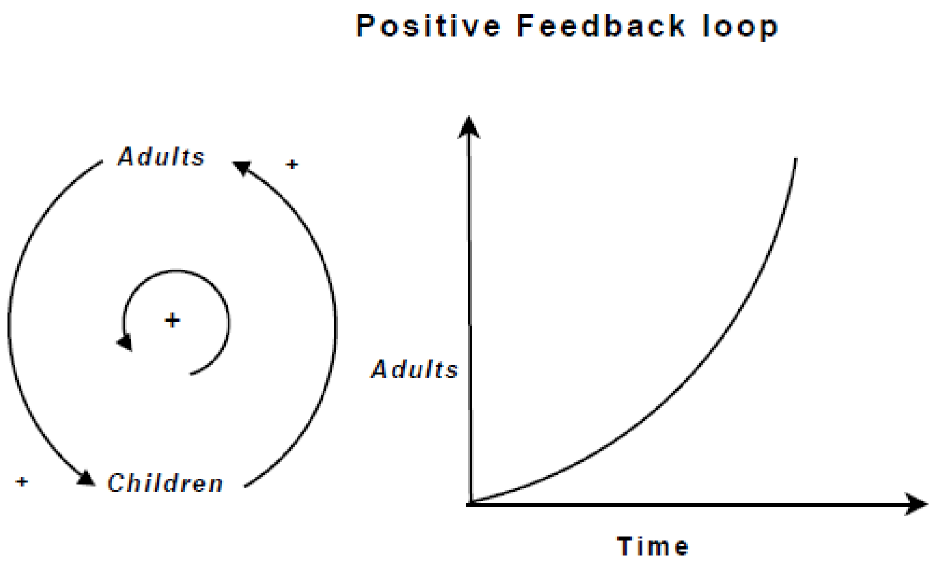


Figure 2.1: Reinforcing feedback loop

- Negative (Balancing) Feedback loop - This loop is represented by a negative sign in the center of the feedback loop. A negative loop contains an odd number of negative causal links. This loop is also called a goal seeking loop, which means the variable values are increased or decreased with time by the loop structure to meet the goal requirements. Figure 2.2 shows a balancing loop where the loop structure is trying to meet the goal requirements of the server performance [13].

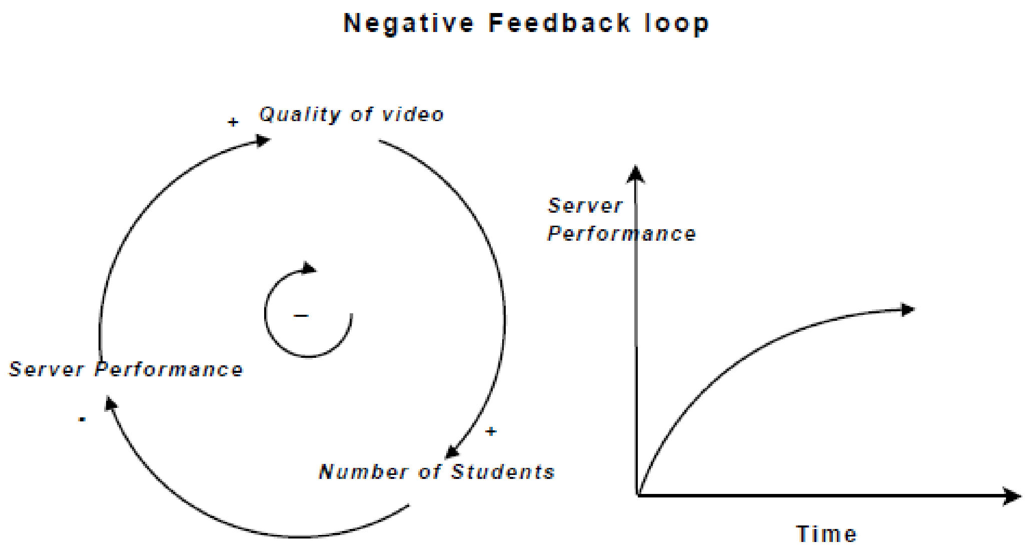


Figure 2.2: Balancing feedback loop

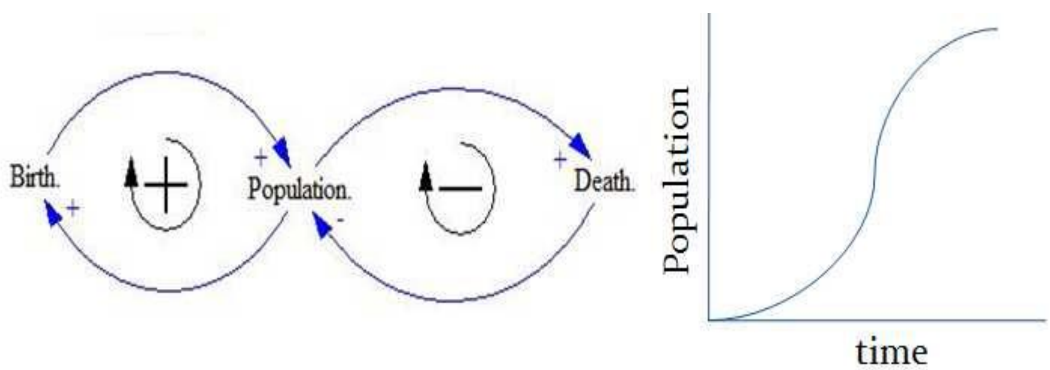


Figure 2.3: Structure involving both positive and negative feedback loops

Figure 2.3 shows a combination of positive and negative feedback loops in the structure. This pattern results in an S-shaped graph representation, where the graph begins with an initial exponential growth, which is followed by a balancing loop effect.

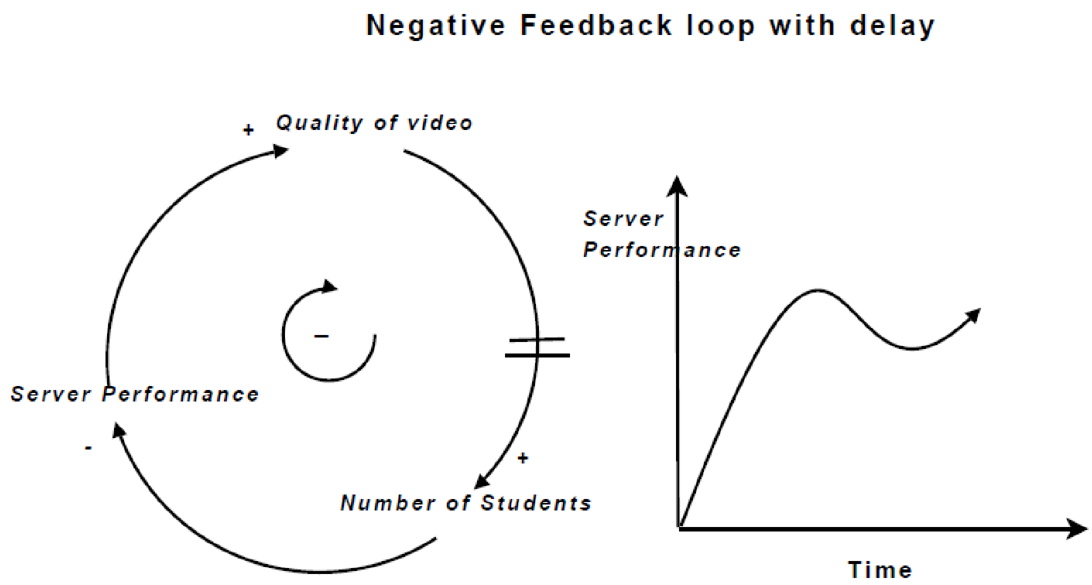


Figure 2.4: Oscillating behavior shown by delays

Figure 2.4 shows the oscillating behavior in a feedback structure when time delays are introduced. The double dash sign indicates the information delay between the quality of video and the number of students. According to the example shown in figure 2.4, server performance increases initially, which decreases as the number of students increases after a certain time delay.

2.2.2. **Stock flow diagram**

"Stock" represents an accumulation of information or material over time and is also called the level variable. The stock flow diagram captures the actual state of the system and can be measured at any instant of time. Stocks are the main source of delays in the system. Flows cause changes to stocks. A flow is the rate at which a stock may increase or decrease over time. Flows are represented in units of time. For example, Number of personal issues affecting students' enthusiasm per week.

Figure 2.5 shows a basic representation for stock flow diagrams, taken from [12]. The inflow determines the rate at which the stock increases over time and the outflow determines the rate at which the stock decreases over time [12].

Figure 2.5. Basic stock flow diagram

The integral equation associated with the stock and flow diagram is as follows [12]:

$$Stock(t) = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Stock(t_0)$$

Apart from the state and rate variables, a stock flow diagram also consists of auxiliary variables. Auxiliary variables are useful in formulating complex rate equations. These variables help make the structure clearer. According to Sterman, auxiliaries consist of functions of stocks (and constants or exogenous inputs) [12]. Figure 2.6 shows a structure consisting of state, rate and auxiliary variables. Student Knowledge is the state variable. Knowledge Gained and Forgetting are the rate variables and Actual Test Performance, Performance Gap and Knowledge Adjustment Factor are the auxiliary variables. Desired Test Performance is an exogenous variable. We can remove the auxiliary variables and reduce the model to a set of equations consisting of only stocks and their flows [12].

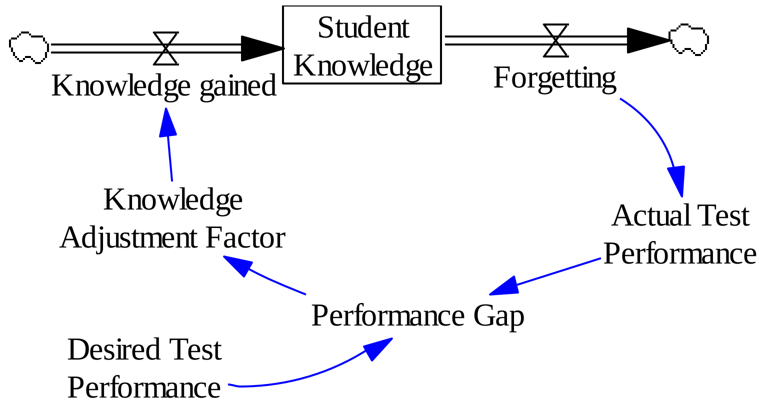


Figure 2.6: Stock flow diagram consisting of state, rate and auxiliary variables.

2.3. **Steps to create a system dynamics model [13]**

1. Recognize a problem associated with a system, such as a teaching/learning process, and identify the components that determine the system's behavior. Define the system boundaries, which will help to establish the problem scope.
2. Create a causal loop diagram that will show various cause-effect relations between variables.
3. Create a stock flow diagram from the causal loop diagram. Identify different types of variables such as level, rate and auxiliary variables.
4. Write equations for all the variables and identify their initial values. We can obtain the initial values from market research data or other data sources.
5. Simulate the model and analyze different trends by using varying variable values.

CHAPTER 3

TOOLS AND METHODS

In this chapter, we discuss our methods for data collection and the tools we used for our system simulation. Data collection helped us to verify our hypotheses and with the tools, it also helped us to simulate the teaching process implemented at a university.

3.1. **Simulation tools**

There are both open source and proprietary tools available for users to perform system dynamics modelling simulations. Some of the most popular ones are listed below [17] [18]. Our choice was Vensim.

- Vensim is available in different configurations under a commercial license and supports both Windows and Macintosh. The Vensim PLE version is free only for educational and personal use.

  Website- http://vensim.com/

- Powersim Studio is available in different configurations under a commercial license and supports Windows. Besides system dynamics modelling, Powersim also supports discrete event modelling. Educational licenses and a free version of Studio Express are available.

  Website- http://www.powersim.com

- STELLA is also available in different configurations under a commercial license and supports both Windows and Macintosh systems. STELLA's model builder is based on an intuitive icon-based graphical interface.

  Website- http://iseesystems.com

3.1.1. **Why choose Vensim?**

Vensim has a rich feature set focusing on quality of model, flexible distribution, connections to data, and advanced algorithms. This software offers its benefits to everyone from students to professionals [19].

Some of the advantages of Vensim are as follows-

- Causal tracing- This feature helps the user to discover which variables cause a particular variable to change.
- Subscripting- This feature enables the user to repeat a structure within a system. The Vensim subscripting language allows construction of advanced array models.
- Model Calibration- Vensim accepts a time series data collected in the "real world" to perform system validation.
- Cost effective- Vensim PLE is a fully functional system dynamics software and is free for personal and educational purposes.

3.2. **Data collection methods**

For the purpose of model validation, we collected data from a computer science programming course at Iowa State University (ISU) for one full semester. Data was collected from the instructor, teaching assistants and the students in the form of online surveys for 5 weeks. IRB approval was taken for collecting human data that can found in Appendix A. The survey questions can be found in Appendix B. We emailed the surveys to the participants at the end of the class and asked them to submit their responses by the end of the same day. Participants provided answers to various multiple choice and one-liner questions, which were based on different aspects of their personal and professional life. Apart from surveys, we also collected assignments, lab and test scores from the teachers for the entire class.

3.2.1. **Why choose this data set?**

We chose a programming course at ISU for our data collection, as it is typical of the American teaching procedure implemented at various universities. Moreover, we were able to collect the data easily and ensure system integrity in time. We decided to use the GQM approach for defining the data metrics and for analyzing the feasibility of our goals. GQM (Goal Question Metric) is an efficient software measurement system, which helps in achieving project goals using questions and metrics [20]. There are three levels of GQM:

- Conceptual (Goals) – What to achieve
- Operational (Questions) – How to achieve the goals
- Quantitative (Metrics) – What metrics can one use to answer the questions to know whether or not one is achieving the goals

Our goals, questions and metrics are shown in Appendix C.

3.2.2. **Data validation**

We conducted biweekly surveys that allowed us to analyze the changing behaviors of students and teachers over the entire course duration. These surveys were conducted on fixed days of the week and involved data collection from both lecture and lab classes. Also, participants from different nationalities provided data that helped us incorporate different perspectives in the model. Biweekly data helped us to study delays within various feedback loops that brought our simulation results closer to the real data. For survey validation, we performed tests such as face validation, content validation and construct validation. Also, for checking survey reliability, we performed test-retest reliability and alternate form reliability tests.

Furthermore, we monitored the data on a weekly basis and kept track of any data discrepancies. We contacted the participants through emails to verify the data and thus ensured data integrity. We used simple English in our surveys and provided examples with the questions to give a complete understanding to the participants. For cross validation, we collected both teachers' and students' perspectives for some similar questions.

CHAPTER 4

STUDENTS' GROWTH MONITORING MODEL

In this chapter, we will talk about different model structures we used to simulate the existing teaching process at ISU for one programming course. Using vensim, we developed a causal loop diagram, which exhibits the relationships between various parameters. Subsequently, we prepared an equivalent Stock-flow diagram to model the system and to analyze various behaviors among parameters. We developed the model using an incremental approach. First, I created the base model, where I established the dependencies using my experience and knowledge as a student and a teacher. Then, I expanded the scope of the model and added more parameters with the help of feedbacks from the professors, graduate and undergraduate students of the computer science department at Iowa State University. I validated the model's scope by taking continuous feedbacks from the professors and the students of different courses and ages.

To model the existing teaching process, we first identified the key variables that determine/change the behavior of the system and then established their dependencies on each other. For example, Rate of Students' personal issues and Students' Enthusiasm are two variables that are inversely related to each other. Thus, an increase in the Rate of Students' personal issues will cause a decrease in the value of Students' Enthusiasm. Figure 4.1 shows the causal loop diagram of our students' growth monitoring model. We identified some feedback loops in the system that are shown in the diagram in the form of clockwise and anti-clockwise circular arrows. The sign shown in the center of the loops determine the type of feedback.

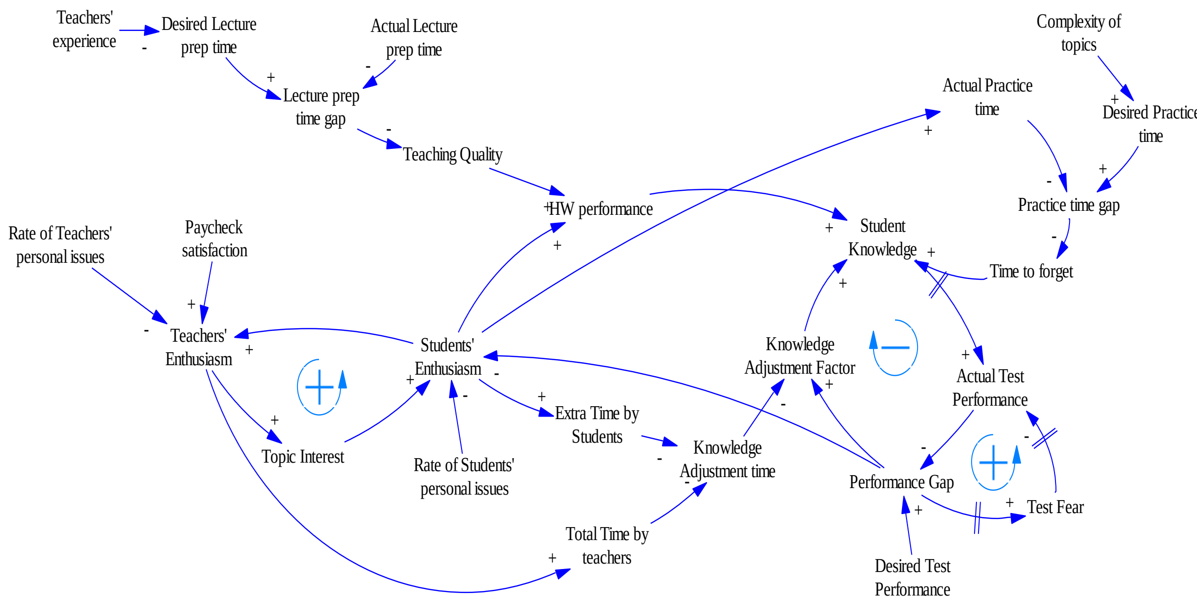


Figure 4.1 Causal loop diagram for existing teaching process

Following are the variables used in the causal loop diagram-

1. Teachers' Enthusiasm- This is the one of the most important variables of the system. The variable depends on Student Enthusiasm, Paycheck satisfaction and Rate of Teachers' personal issues. We assumed the value of this variable to vary between 0 and 1, where 0 denotes no enthusiasm and 1 denotes full enthusiasm.
2. Students' Enthusiasm- This is another important variable of the system. The variable depends on Topic Interest, Performance gap and Rate of Students' personal issues. We assumed the value of this variable to vary between 0 and 1, where 0 denotes no enthusiasm and 1 denotes full enthusiasm.
3. Student Knowledge- This is also an important variable of the system and is defined as the amount of knowledge gained by the students throughout the course duration. The variable depends on Time to forget, HW performance and Knowledge Adjustment

time. We assumed the value of this variable to vary between 0 and 1, where 0 denotes no knowledge gained and 1 denotes full knowledge gained. We define students' knowledge as the amount of course concepts clearly understood by the students.

4. Topic Interest- This is defined as the interest gained by the students for a particular topic. The variable depends on Teachers' Enthusiasm. We assumed the value of this variable to vary between 0 and 1, where 0 denotes no interest and 1 denotes full interest.
5. Paycheck satisfaction- This exogenous variable is defined as the teachers' salary satisfaction level. We assumed the value of this variable to vary between 0 and 1, where 0 denotes no satisfaction and 1 denotes full satisfaction.
6. Rate of Teachers' personal issues- This exogenous variable is defined as the number of personal issues experienced by the teachers per week. We will take the value for this variable as a time series data over the entire course duration.
7. Rate of Students' personal issues- This exogenous variable is defined as the number of personal issues experienced by the students per week. We will take the value for this variable as a time series data over the entire course duration.
8. Extra time by students- This is defined as the extra amount of hours provided by the students to learn/clarify the concepts. The variable is dependent on Students' Enthusiasm.
9. Total time by teachers- This is defined as the total number of regular and extra hours provided by the teachers to help the students. The variable is dependent on Teachers' Enthusiasm.
10. Teachers' Experience- This is defined as the amount of experience a teacher possess in terms of domain knowledge, experience in teaching a particular course and number of

times a particular course is taught by previous teachers. We assumed the value of this variable to vary between 0 and 1, where 0 denotes no experience and 1 denotes full experience.

11. Desired Lecture prep time- This is defined as the ideal number of hours required by the teachers to prepare for class sessions. The variable is dependent on Teachers' experience. If a course is taught by previous teachers, then a new teacher will save significant amounts of course work preparation time. Moreover, a teacher will not spend a large amount of time preparing for class sessions if he or she has prior experience in teaching the same course. Thus, Desired Lecture prep time will be less in the above cases.
12. Actual Lecture prep time- This exogenous variable is defined as the number of hours provided by the teachers in reality to prepare for class sessions. We will take the value for this variable as a time series data over the entire course duration.
13. Lecture prep time gap- This is defined as the gap between Desired Lecture prep time and Actual Lecture prep time.
14. Teaching Quality- This variable depends on Lecture prep time gap. An increase in the value of Lecture prep time gap will decrease Teaching Quality. We assumed the value of this variable to vary between 0 and 1, where 0 denotes worst case and 1 denotes the best case.
15. Homework (HW) performance- This variable depends on Students' Enthusiasm and Teaching Quality. High student enthusiasm and better teaching quality will result in better student homework scores.

16. Actual Practice time- This is defined as the amount of hours provided by the students to practice the course topics. The variable depends on Students' Enthusiasm. High Students' Enthusiasm will result in more hours provided by the students to practice the topics.
17. Complexity of topics- We assumed the value of this variable to vary between 0 and 1, where 0 denotes least complex and 1 denotes very complex. We will take the value for this exogenous variable as a time series data over the entire course duration.
18. Desired Practice time- This is defined as the ideal number of hours required by the students to practice the topics. We obtained the ideal number of hours from the data collected for practice time spent by the students getting 100% scores in their assignments. The variable is dependent on Complexity of topics.
19. Practice time gap- This is defined as the gap between Desired Practice time and Actual Practice time.
20. Time to forget- This is defined as the amount of time taken by the students in weeks to forget the knowledge they gained so far over the course duration. The variable is dependent on Practice time gap. Student will tend to forget the gained knowledge if they do not practice the topics well.
21. Actual Test performance- This is defined as the percentage of students' test scores. The variable depends on Student Knowledge and Test fear.
22. Desired Test performance- This is defined as the ideal test scores desired by the students. We took a constant value for this variable as 92 percent.
23. Performance gap- This is defined as the gap between Desired Test performance and Actual Test performance. We started capturing the value of this variable from the 2.5th

week (tests were conducted every 2.5 weeks) assuming there was no performance gap from week 0 to week 2.5

24. Test Fear- This is defined as the degree of anxiety students' face during the tests. We assumed the value of this variable to vary between 0 and 1, where 0 denotes least and 1 denotes most. The variable depends on Performance gap. Low test scores increases the test anxiety among the students.
25. Knowledge Adjustment Time- This is defined as the amount of time in weeks required to recover the Performance gap. The variable depends on Extra time by students and Total time by teachers. Students can recover the performance gap in small time if students and teachers provide sufficient extra time to discuss/clarify the concepts.
26. Knowledge Adjustment factor- This is defined as the amount of knowledge recovered to bridge the Performance gap in a specific amount of time. The variable is dependent on Performance gap and Knowledge Adjustment Time. We assumed the value of this variable to vary between 0 and 1 where 0 will denote no knowledge adjustment and 1 denotes full knowledge adjustment.

The causal loop diagram in figure 4.1 shows negative and positive feedback loops. The presence of a negative feedback loop depicts a goal seeking behavior within our system. The goal in our model is to achieve the Desired Test performance value. A detailed Stock flow diagram for our model is shown in figure 4.2.

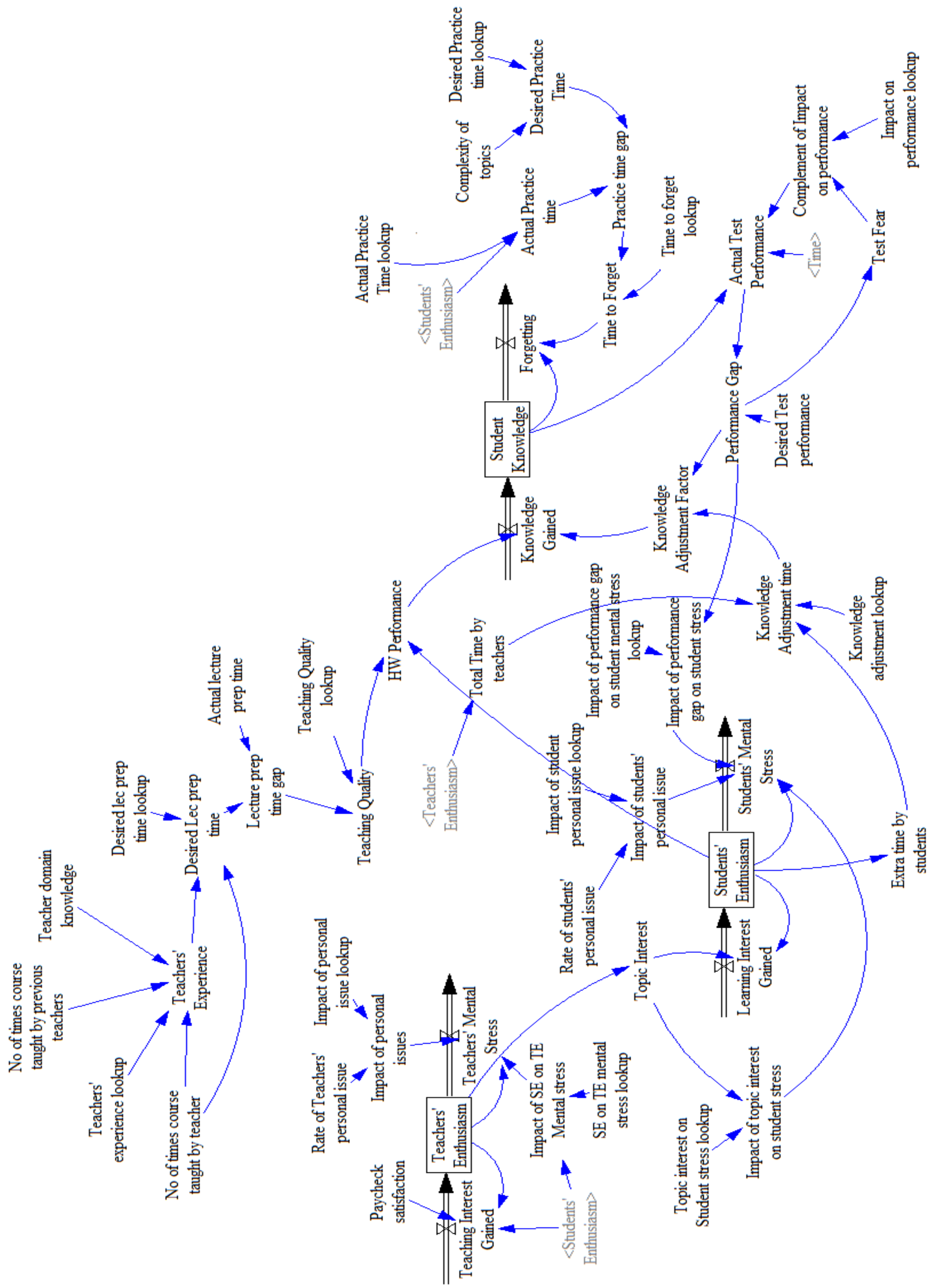


Figure 4.2: Stock flow diagram for the teaching process.

The Stock flow diagram in figure 4.2 uses many lookup variables. We plotted the input graphs for the lookup variables in Vensim on the basis of our own experience and professors' feedbacks. Also, we defined some new rate and exogenous variables to quantify the models in table 4.1. We calculated the initial values of stocks and constants' values using the data obtained from the computer science programming class. All the initial values are obtained by aggregating the values obtained during the data collection of each input variable for week 1. For example, we calculated the average of all the values collected from the students for teachers' enthusiasm for the two surveys conducted in week 1.

Table 4.1 shows various equations used in the Stock flow diagram.

Table 4.1: Equations of various important variables

Variable Name	**Initial Value/Equation/Range**	**Unit**
Teachers' Enthusiasm (TE)	0.86, $\int_0^t [Teaching\ Interest\ Gained(s) - Teachers'Mental\ Stress(s)]ds + Initial(TE)$, varies between 0 and 1	Dmnl*
Students' Enthusiasm (SE)	0.84, $\int_0^t [Learning\ Interest\ Gained(s) - Students'Mental\ Stress(s)]ds + Initial(SE)$, varies between 0 and 1	Dmnl
Teaching Interest Gained	(1-Teachers' Enthusiasm)*Paycheck satisfaction*Students' Enthusiasm, varies between 0 and 1	Dmnl
Teachers' Mental Stress	Teachers' Enthusiasm*(Impact of personal issues+ Impact of SE on TE Mental stress), varies between 0 and 1	Dmnl
Paycheck satisfaction	0.6, varies between 0 and 1	Dmnl
Topic Interest	Teachers' Enthusiasm, varies between 0 and 1	Dmnl
Rate of students' personal issues	4, 0, 2, 1, 3	Issues/week

Table 4.1 continued.

Learning Interest Gained	Topic Interest*(1-Students' Enthusiasm), varies between 0 and 1	Dmnl
Students' Mental Stress	Students' Enthusiasm*(Impact of performance gap on student stress +Impact of students' personal issue+ Impact of topic interest on student stress), varies between 0 and 1	Dmnl
Rate of Teachers' personal issues	2, 1, 2, 1, 0	Issues/week
Knowledge Adjustment time	Knowledge adjustment lookup(Extra time by students+ Total Time by teachers)	Week
Knowledge Adjustment Factor	Performance Gap/(100*Knowledge Adjustment time), varies between 0 to 1	Dmnl
Performance Gap	0+STEP(MAX(Desired Test performance-Actual Test Performance,0),2.5)	percent
Knowledge Gained	(0.125*(HW Performance/100))+Knowledge Adjustment Factor	Dmnl
Student Knowledge(SK)	0.34, $\int_0^t [Knowledge\ gained(s) - Forgetting(s)]ds + Initial(SK)$, varies between 0 and 1	Dmnl
Forgetting	MIN(1,Student Knowledge/Time to Forget)	Dmnl
Time to Forget	If students’ practice time gap is less than 0, then 80 weeks; else Time to forget lookup(Practice time gap))	Week
Actual Test Performance	(Student Knowledge*100*Complement of Impact on performance)/((Time+3)/8)	percent
Desired Test performance	90	percent
Test Fear	DELAY FIXED(Performance Gap/100,0.4,0.04), varies between 0 to 1	Dmnl
Practice time gap	MAX(Desired Practice Time-Actual Practice time,0)	Hours/week
Actual Practice time	Actual Practice Time lookup (Students' Enthusiasm)	Hours/week
Desired Practice Time	Desired Practice time lookup (Complexity of topics)	Hours/week
Complexity of topics	0.92, 0.84, 1, 1, 1 (over 5 weeks)	Dmnl
Extra time by students	Students’ Enthusiasm*10	Hours/week

Table 4.1 continued.

Total Time by teachers	5+(Teachers' Enthusiasm*2)	Hours/week
HW Performance	Students' Enthusiasm*Teaching Quality*100	percent
Teaching Quality	Teaching Quality lookup(Lecture prep time gap), varies between 0 to 1	Dmnl
Lecture prep time gap	MAX(Desired Lec prep time-Actual lecture prep time,0)	Hours/week
Desired Lec prep time	If teacher has taught a course more than 4 times, then 0.25; else Desired lec prep time lookup(Teachers' Experience)	Hours/week
Actual lecture prep time	3.83, 4, 5.1, 3.3, 3.7, 5 (over 5 weeks)	Hours/week
Teachers' Experience	If teacher has taught a course more than 10 times, then 0.4; else (Teachers' experience lookup(No of times course taught by teacher) + if (teacher has taught course less than 2 times, then 0.25*((0.5*Teacher domain knowledge)+(0.5*MIN(No of times course taught by previous teachers/3,1))); else 0)) Varies between 0 and 1	Dmnl
No of times course taught by teacher	0	Dmnl
Teacher domain knowledge	0.8, varies between 0 and 1	Dmnl
No of times course taught by previous teachers	3	Dmnl
Complement of Impact on performance	Impact on performance lookup(Test Fear)	Dmnl
Impact of performance gap on student stress	Impact of performance gap on student mental stress lookup (Performance Gap)	Dmnl

* Dimensionless

The definitions of some constants used in variable equations are as follows-

Table 4.2: Constants used in the equations

Variable	**Constant name**	**Constant value**
Performance Gap	Frequency of conducting tests	2.5 weeks
Knowledge Gained	Maximum amount of knowledge obtained from homework performance per week	0.125 (Course duration 8 weeks. Thus, Total knowledge/8)
Actual Test Performance	Course duration Test conducting week	8 weeks 3^{rd} week
Total Time by teachers	Maximum extra time given by teachers Regular time given by teachers	2 hours/week 5 hours/week

CHAPTER 5

RESULTS AND ANALYSIS

In this chapter, we will verify the hypotheses based on our research questions using the simulation results obtained from our model. We performed simulation runs for a time period of 5 weeks for a programming class at ISU with varying values of different variables. The input variables of our model are as follows (see Table 4.1):

- Complexity of topics
- Rate of students' personal issue
- Rate of teachers' personal issue
- Paycheck satisfaction
- No of times course taught by teacher
- No of times course taught by previous teachers
- Teacher domain knowledge
- Actual lecture prep time.

We made the following assumptions while performing our simulations:

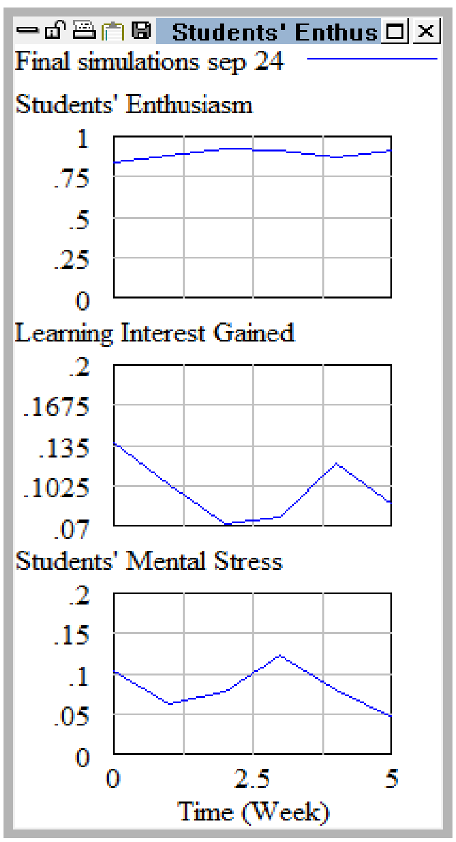
1. All personal issues have the same severity. Therefore, we calculated the impact of personal issues on the basis of the total count rather than the severity level.
2. Students do not face any major language issues such as difficulty in speaking or difficulty in comprehending the English language. This assumption is based on the fact that international students coming to US universities have met the English speaking/writing/listening standards.

3. The model is derived from the information gathered from undergraduate and graduate students. Thus, the results can be only be considered valid, at best, for graduate and undergraduate courses at various American universities.

5.1. **Hypothesis verification**

Hypothesis 1: Teachers' enthusiasm has a significant impact on the learning interest of students in class

To verify this hypothesis, we used the following simulation results obtained from our model.



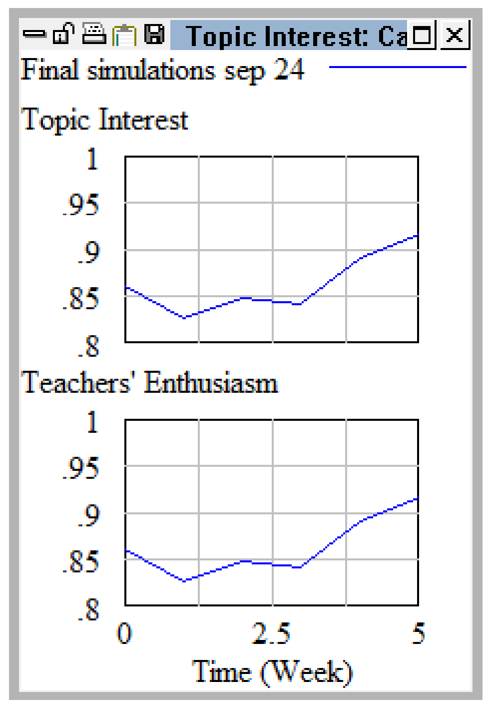


Figure 5.1: Change in Students' Enthusiasm using varying values of Learning Interest Gained and Student Mental Stress.

Figure 5.2: Change in Topic Interest using varying values of Teachers' Enthusiasm

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In figure 5.2, we can clearly see that the value of Topic Interest is dependent on Teachers’ Enthusiasm. We observe that as Teachers’ enthusiasm decreases from 0.86 to 0.83 in week 1, the value of Topic Interest also decreases from 0.86 to 0.83 at the same time.

From figure 5.1 and 5.2, we can say that as Teachers’ Enthusiasm decreases from 0.86 to 0.83 in week 1, the value of Learning Interest gained by the students also decreases, from 0.135 to 0.103 for the same time period. Also, as Teachers’ Enthusiasm increases from 0.85 to 0.89 in week 4, Learning Interest gained increases from 0.08 to 0.11 for the same time period.

From this analysis, we can conclude that teachers with high enthusiasm make the topic very interesting for the class. As the topic interest increases, students’ curiosity to learn also increases.

Hypothesis 2: Students cannot completely remember what they learn over the course for a lifetime. The time to forget this knowledge will depend on the complexity of the course and the time put in by the students to practice the topics.

In figure 5.4, we can clearly see that the value of Desired Practice Time decreases from 9 to 7 hours in week 1 as the value of Complexity of topics decreases from 0.92 to 0.84 for the same time period. Similarly, the value of Desired Practice Time increases from 7 to 12.25 hours in week 2 as the value of Complexity of topics increases from 0.84 to 1 for the same time period.

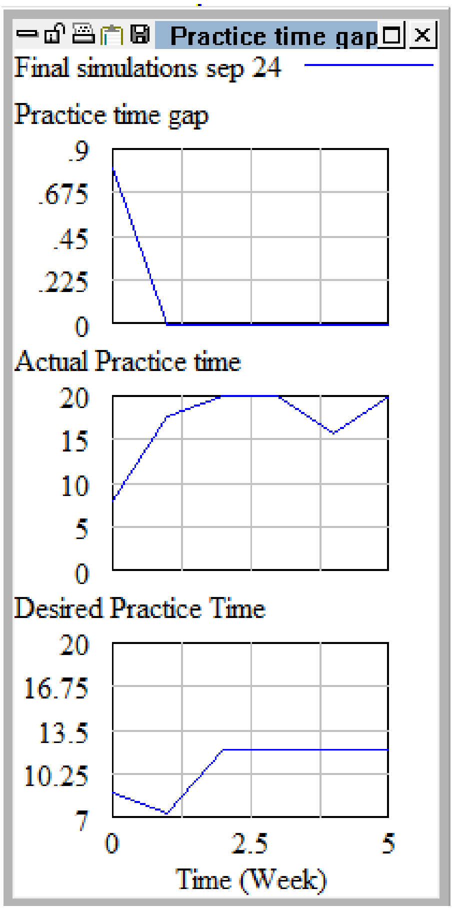


Figure 5.3: Change in Practice time gap using varying values of Actual Practice time and Desired Practice Time.

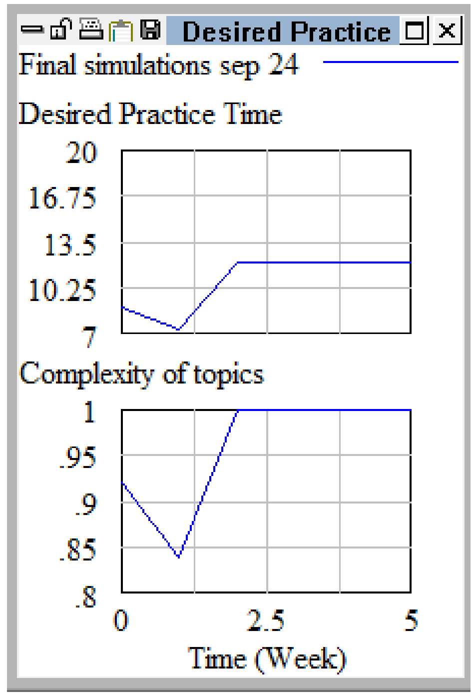


Figure 5.4: Change in Desired Practice Time using varying values of Complexity of topics

From figure 5.3, we can observe that there is a Practice time gap of 0.9 hours in week 0 as the value of Actual Practice Time is less than Desired Practice Time at that time. Similarly, we can see that there is no Practice time gap when the value of Actual Practice Time is at least equal or greater than Desired Practice Time.

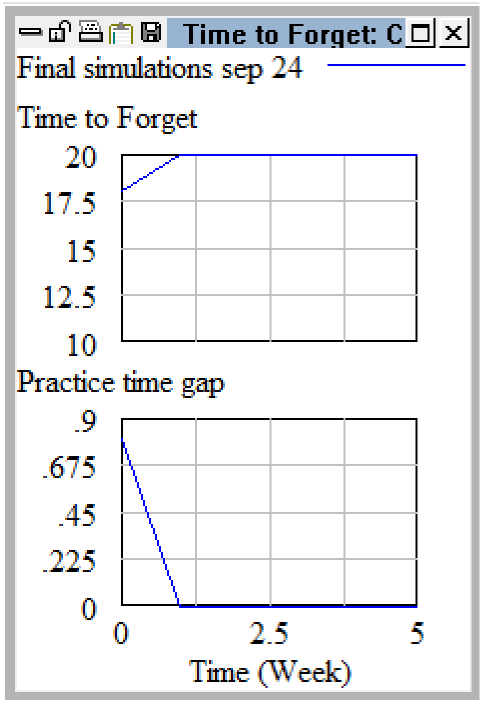
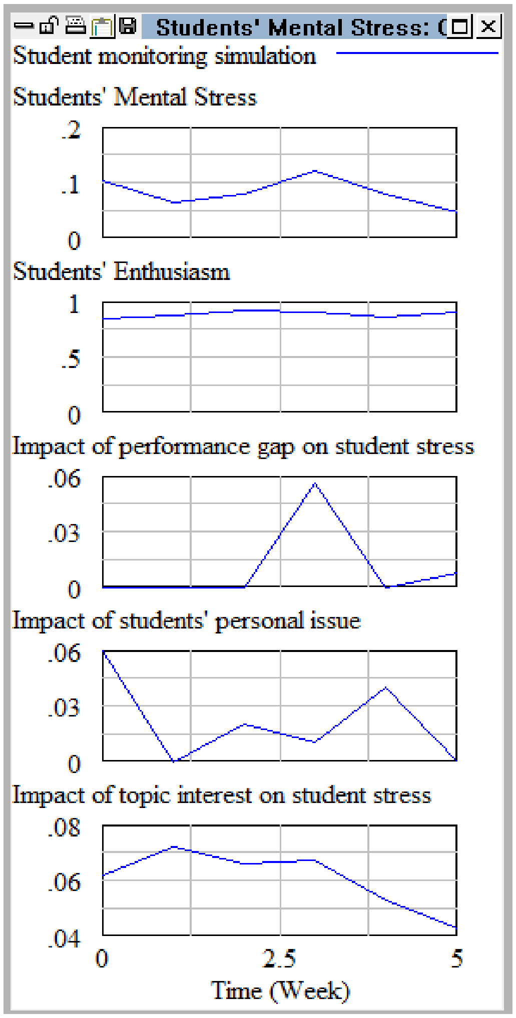


Figure 5.5: Change in Time to forget using varying values of Practice time gap.

From figure 5.5, we can see that as the value of Practice time gap decreases in week 1, Time to forget the knowledge gained in the class increases. When the Practice time gap reaches 0, the value of Time to forget the knowledge reaches a very high value, which is 20 weeks in our case.

From the above statements, we can clearly conclude that students will retain knowledge for a very long period of time if they provide the desired amount of effort in practicing the topics. We know that the human mind cannot retain 100% knowledge for eternity for various reasons. Thus, according to our experience, we took the highest value of Time to forget as 20 weeks. Also, the amount of time required to practice the topics depends on the topics' complexity. Thus, the effort to practice difficult topics is always more.

Hypothesis 3: Performance gap, the difference between students' desired grade and students' actual grade on exams, affects students' enthusiasm and builds test anxiety for students.



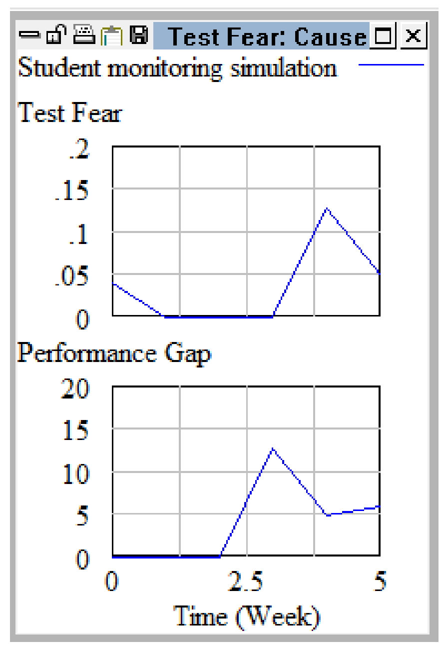


Figure 5.6: Change in Students' Mental Stress using varying values of Impact of performance gap on student stress, Impact of topic interest on student stress and Impact of personal issues.

Figure 5.7: Change in Test Fear using varying values of Performance gap

In figure 5.7, we can clearly see that as Performance gap increases from 0 to 13 percent in week 3, Test fear also increases from 0 to 0.13 in week 4. Similarly, as Performance gap decreases in week 4, Test fear also decreases in week 5.

From figure 5.6 and 5.7, we can observe that the value of Impact of performance gap on student stress increases from 0 to 0.05 in week 3 as Performance gap increases for the same time period. Furthermore, an increase in the value of Impact of performance gap on student stress in week 3 increases Students' Mental Stress value for the same time period. Thus, Students' Enthusiasm value decreases from 0.86 to 0.83 in week 4 when Students' Mental Stress increases in week 3.

Similarly, we can say from figure 5.6 that Students' Enthusiasm is also affected by variables such as Impact of students' personal issue and Impact of topic interest on student stress.

From the above analysis, we conclude that bad test scores increase the pressure among the students to do better in the following tests and as a result, increase test anxiety. Moreover, bad test scores decreases students' morale and thus, decreases students' class enthusiasm.

Hypothesis 4: Students' enthusiasm has a reciprocal effect on teachers' enthusiasm. For example, an increase in students' enthusiasm will increase teachers' enthusiasm.

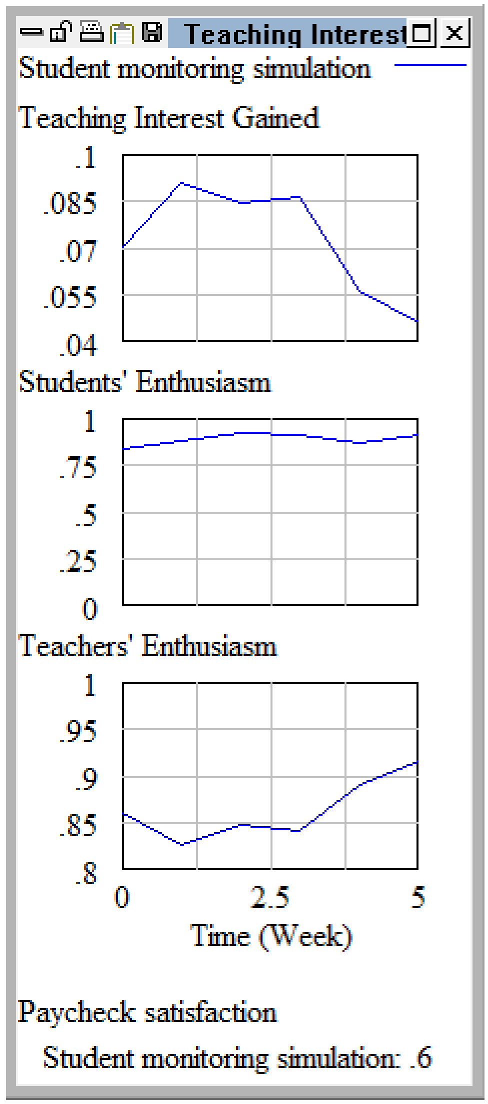


Figure 5.8: Change in Teachers' Enthusiasm using varying values of Students' Enthusiasm.

From figure 5.8, we can observe that as Students' Enthusiasm increases from 0.84 to 0.86 in week 1, the value of Teaching Interest gained also increases from 0.7 to 0.88 for the same time period. Furthermore, the value of Teachers' Enthusiasm increases from 0.83 to 0.85 in week 2 as the value of Teaching Interest gained increases in week 1.

We previously observed from figure 5.1 and 5.2 that Teachers' Enthusiasm has a direct effect on Students' Enthusiasm. Thus, there is a feedback effect from Students' Enthusiasm on Teachers' Enthusiasm.

We can conclude from the above analysis that high students' enthusiasm increases teachers' enthusiasm to teach effectively and help students more in the class.

Hypothesis 5: Performance gap can be reduced over time if students stay motivated and work with their teachers on their problems.

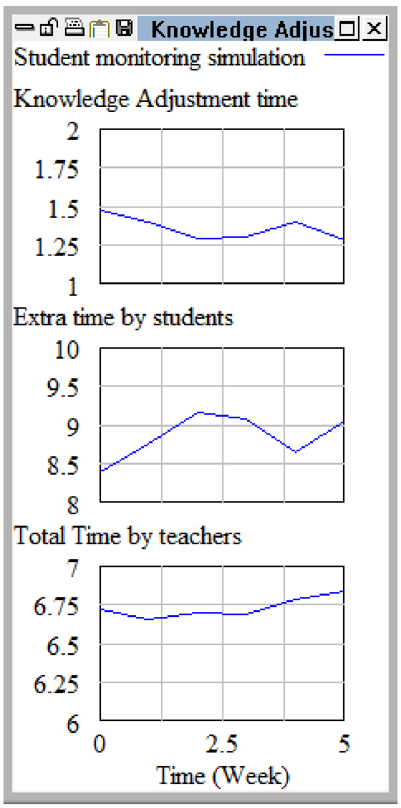


Figure 5.9: Amount of extra time provided by the students and the teachers to learn about the topics.

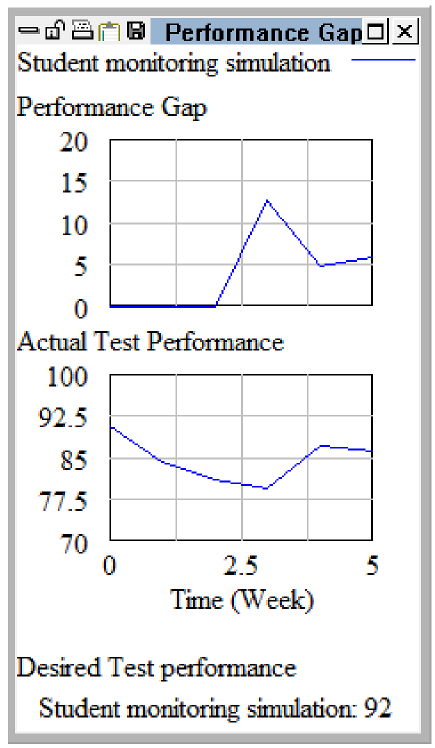


Figure 5.10: Change in Performance gap using varying values of Actual Test Performance and Desired Test Performance

From figure 5.9 and figure 5.10, we can observe that when the value of Extra time by students is 9.1 hours and Total time by teachers is 6.65 hours in week 3, Actual Test Performance value increases from 79 to 86 percent in week 4. Subsequently, Performance gap decreases from 13 to 5 percent in week 4.

Thus, we can conclude from the above analysis that when extra effort is provided by the students and teachers to clarify the concepts, students get better scores and the performance gap decreases.

Hypothesis 6: Teaching quality and students enthusiasm affects students' homework performance.

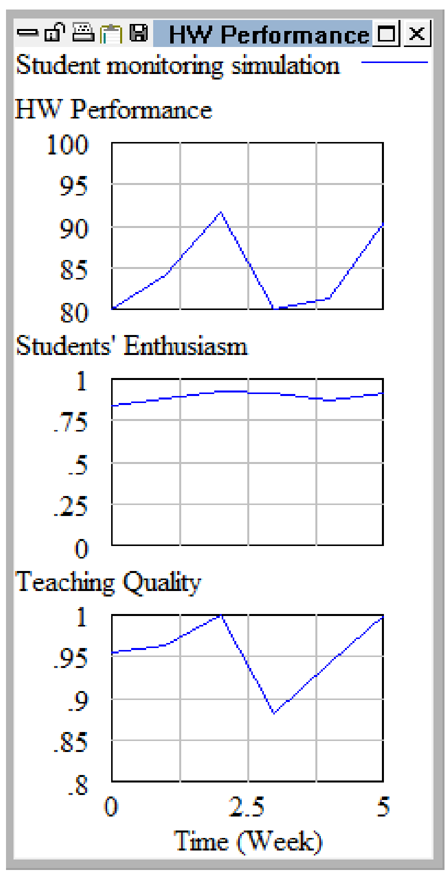


Figure 5.11: Change in Homework Performance using varying values of Teaching Quality and Students' Enthusiasm.

From figure 5.11, we can observe that when the value of Students' Enthusiasm and Teaching Quality increases from week 0 to week 2, the value of Homework performance also increases from 80 to 91 percent at the same time period. Similarly, when Teaching Quality and Students' Enthusiasm decrease from week 2 to week 3, Homework Performance also decreases from 91 to 80 percent at the same time period.

Thus, we conclude that students understand the concepts better when the quality of teaching is high and when students show high enthusiasm about the subject.

Hypothesis 7: Personal issues affect teachers' enthusiasm and students' enthusiasm.

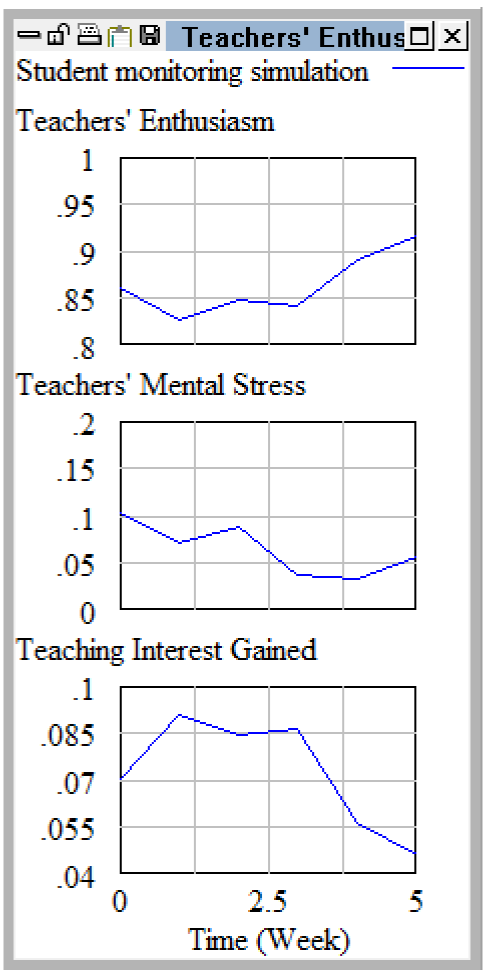


Figure 5.12: Change in Teachers'

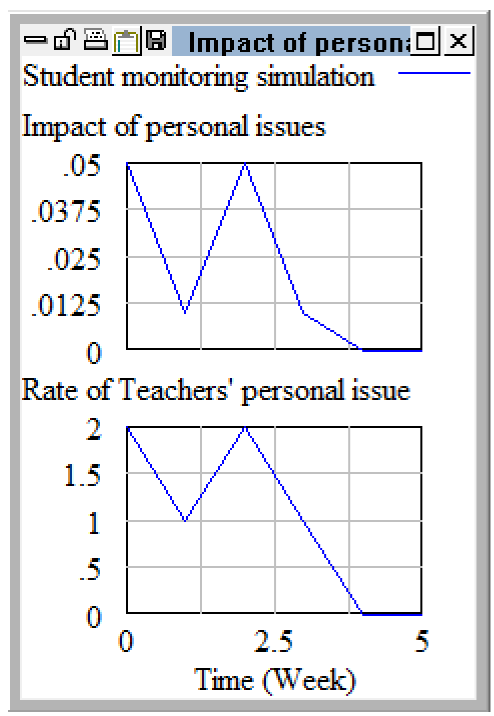


Figure 5.13: Change in Impact of

Enthusiasm using varying values of Teachers' Mental Stress and Teaching Interest Gained

personal issues using varying values of Rate of Teachers' personal issue

From figure 5.12 and 5.13, we can observe that when the Rate of Teachers' personal issues is 2 at week 0 and week 2, the value of Teachers' Mental Stress goes up to 0.1 in week 0 and 0.9 in week 2. Subsequently, high values of Teachers' Mental Stress decreases Teachers' Enthusiasm to 0.83 in week 1 and 0.85 in week 3.

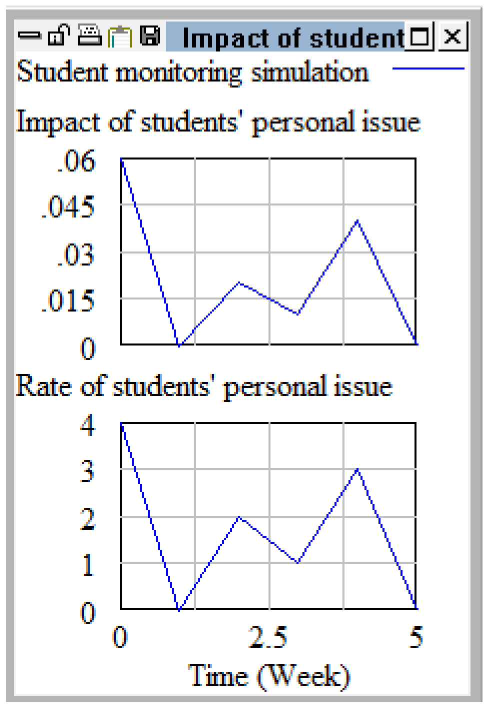


Figure 5.14: Change in Impact of students' personal issues using varying values of Rate of students' personal issue

Similarly from figure 5.1 and 5.14, we can say that when Rate of students' personal issues increases from 0 to 2 in week 2, the value of Students' Mental Stress also increases from 0.6 to 0.75 at the same time period. Subsequently, an increase in Students' Mental Stress decreases Students' Enthusiasm from 0.9 to 0.8 in week 3.

Thus, we can conclude that personal issues increase mental stress for both the teachers and the students and result in low class enthusiasm.

Hypothesis 8: Course complexity does not impact students' performance for students who practice the topics well and stay motivated.

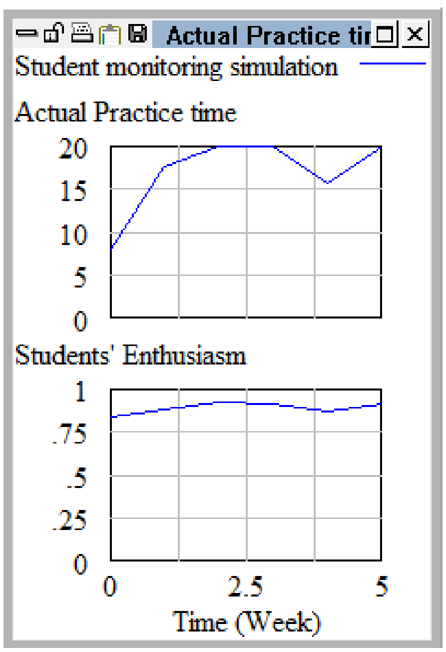


Figure 5.15: Change in Actual Practice time using varying values of Students' Enthusiasm.

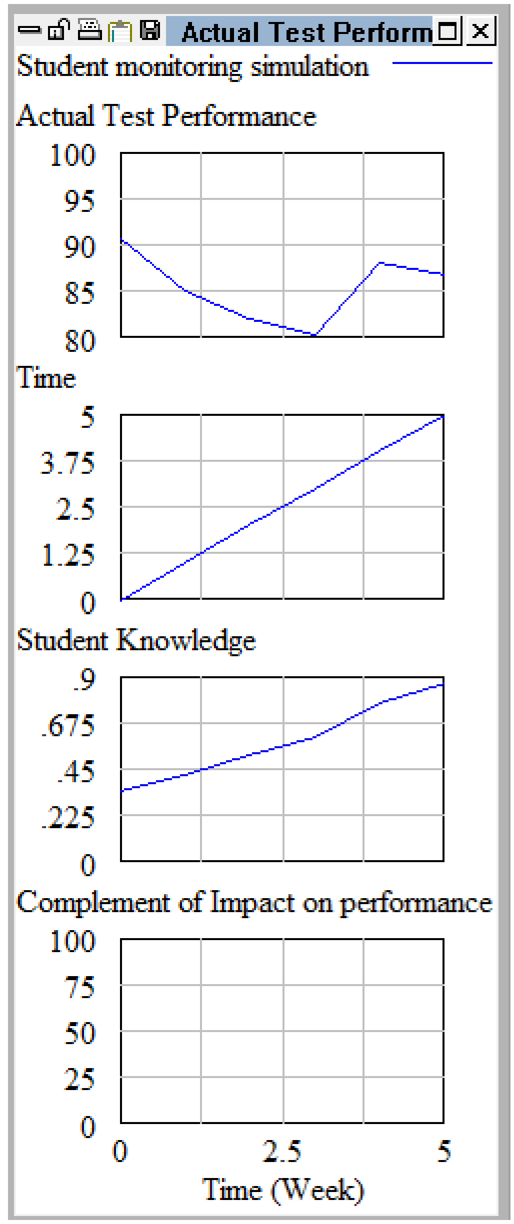


Figure 5.16: Change in Actual Test Performance using varying values of Students' Knowledge.

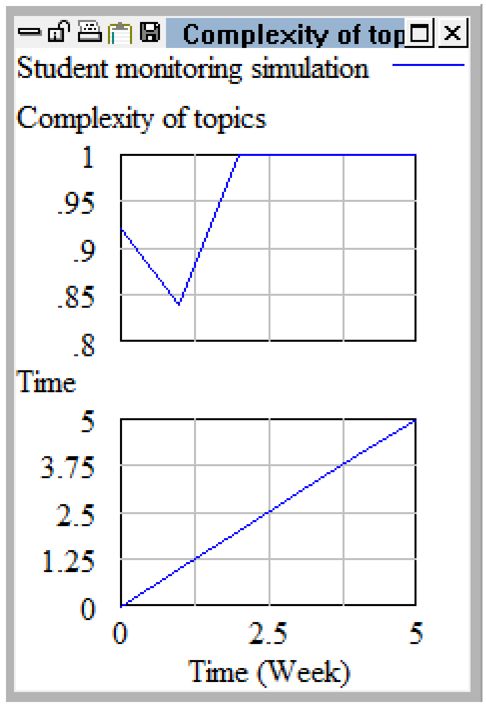


Figure 5.17: Varying values of Complexity of topics over time.

From figures 5.15, 5.16 and 5.17, we can see that when Complexity is 1, Students' Enthusiasm is 0.9 and Actual Practice time is 20 hours in week 2, the value of Students' knowledge is still increasing during week 3 and Actual Test performance increases from 78 to 86 percent at the same time period.

Thus, we can conclude that students can gain appropriate knowledge about very complex topics if they are self-motivated and practice the topics well. In the above situation, the test performance of the class is not affected when very complex topics are taught to the students.

5.2. Data verification

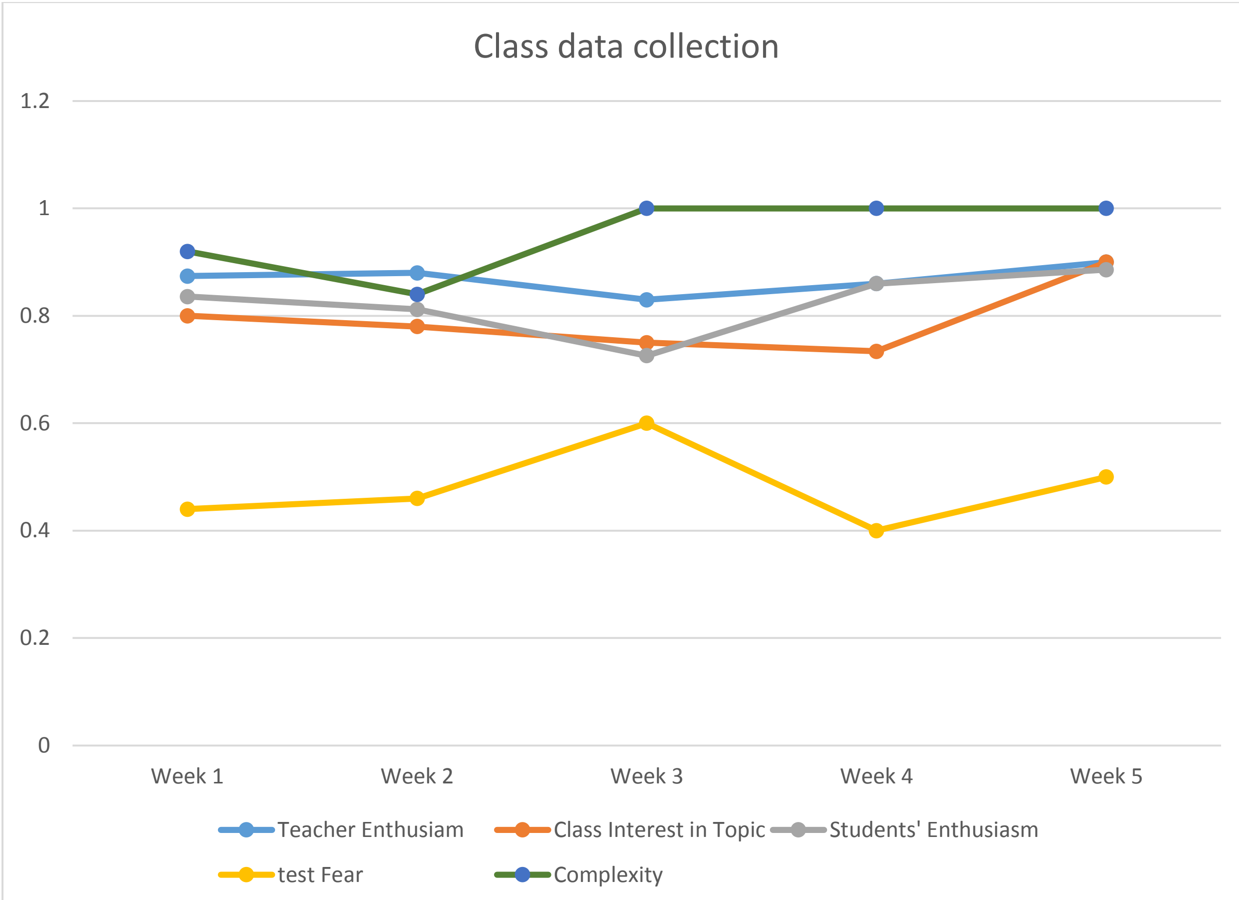


Figure 5.18: Data obtained from computer science programming course for various variables.

Table 5.1: Comparison between simulation results and actual results for Test Performance

Week	Simulation result for Test Performance	Test Performance results from class	% difference
0	91%	90.75%	0.3%
3	78%	84%	7.1%
5	85%	90.50%	6.1%

We compared the values obtained from our simulations to the data shown in figure 5.18 and table 5.1. We found that our simulation results showed similar trends when compared to the actual data. For example, students' enthusiasm experiences a drop around the 3rd week and test fear value increases around the 3rd week both in the actual data as well as the simulation results. For validating the causal dependencies between various parameters, we showed our simulation results to the instructor of the programming course and took his feedback. Based on his feedback, we were able to conclude that the trend variations showed by our simulations were actually experienced by all the course teachers and students for those particular weeks. We are not very sure about the accuracy of our data, but we were able to capture the true trends and prove that such study is feasible. Thus, we concluded that our model was able to capture true trends and relations among various parameters. However, the model showed a maximum difference of around 7% for the variables' values when compared to the actual data.

5.3. **Limitations**

- It was not possible to customize the stock delays within the model for variables such as students' enthusiasm and teachers' enthusiasm.
- We did not consider variables such as impact of city environment, gender, professor reputation within our model because of lack of information.
- We did not consider the severity of personal issues in our model because of lack of time and privacy issues. As a result, there was a lack of accuracy in the calibration of impact of students' and teachers' personal issue.
- We did not have the time to validate how students implement the attained knowledge after course completion using real life projects. This type of verification would have allowed us to validate the accuracy of students' knowledge.

- It was very challenging to persuade students to participate in our voluntary surveys. Also, we had to reject data from various participants because of incompleteness in their answers. Thus, we were able to consider useful/valid data from only 4 students and 3 teachers because of various data error issues. In spite of this limitation, we were able to prove through our study that the simulation of an existing teaching process is feasible.

CHAPTER 6

CONCLUSION AND FUTURE WORK

In our study, we modelled the existing teaching process from a systems' behavior perspective. By analyzing the dependencies among various variables in our structure, we obtained insights into the problems impacting students' performance. Moreover, simulation results allowed us to provide recommendations to the universities about how to improve the teaching program. The suggestions are based on our own experience, students' feedbacks from the programming class and on various research conducted in this sector [22, 23, 24].

We found that students' enthusiasm in class can be increased significantly if teachers' enthusiasm is high and if the topic taught in class is made very interesting by the teachers. Some suggestions to increase student topic interest are by using picture presentations, motivating examples and interactive study in class. We found that students' performance gap can be decreased if students provide extra effort in clarifying their concepts with the teachers. Some suggestions to achieve this goal are to maintain a friendly behavior in the class and encourage students to meet with the teachers on a weekly basis to discuss their problems. Group meetings or personal meetings should be organized based on students' requirements.

We also concluded that personal issues may increase mental stress among the teachers and the students. Some suggestions to reduce students' mental stress are to organize personal meetings with the students to understand their problems or in worst cases contact their parents/guardians who can encourage them properly. To reduce teachers' mental stress, universities should arrange for on campus consultancy that may help teachers to resolve their issues.

A significant observation from our data and model analysis was that the impact of students' personal issues on their mental stress was less in magnitude in comparison to the impact of performance gap. This gave us an idea that students might be trying to divert their mind from their personal problems by paying attention in class. However, we believe that the magnitude of personal issues impact may vary depending on different countries, culture, gender and how far away from home a student is [22].

Another important observation we made from our data collection was that text anxiety or test fear does not impact students' test performance below a certain threshold value. Moreover, the impact of test anxiety is low in magnitude and decreases the students' test performance at a very slow rate when test anxiety value goes beyond the threshold value.

Finally, we observed that students attain the desired amount of knowledge from a course if the teaching quality is high and students' enthusiasm is high. To ensure high teaching quality, universities should select a teacher with sufficient domain experience in the course. . Moreover, teachers should provide more effort in lecture preparation if there is little course material available and if the teacher does not have any prior experience in teaching that course. However, we believe that students' level of concept understanding in the class also depends on teachers' way of teaching. Many researchers are trying to study the relation between the teaching style and the learning style [21].

The system dynamics modelling technique can be used by the universities in predicting students' performance for any graduate or undergraduate course. The simulation results will present early warnings of the possible pitfalls in the plans that will allow the universities to take preventive measures and prepare an efficient teaching strategy for a course. By changing the values of different variables, users can answer their questions on what factors can help them to reach the desired students' performance value. For example, users can vary the value of actual lecture preparation time a teacher should provide in order to obtain the desired value of students' homework performance.

As continuation of this work, our model can be extended to simulate teaching processes in various international universities. New variables such as language issues, culture, gender, professor's reputation, city environment, severity of personal issues and many others can be added to make the model more precise. Also, our model can be modified to simulate high school teaching processes. Results can be validated by collecting data from a sufficient number of students and teachers of different course types and from different academic fields. We can also validate the accuracy of students' knowledge value by analyzing how students implement the attained knowledge after course completion using real life projects. We think that some variables related to teachers' teaching style can be added in the model. These variables will provide better accuracy results for students' enthusiasm.

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APPENDIX A

IRB APPROVAL FORM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 [illegible]

Date:	6/5/2015		
To:	Vidushi Sukhwal 4324 Westbrook Dr, Unit 37 Westbrook Terrace, Ames, IA	**CC:**	Dr. David Weiss 229 Atanasoff
From:	Office for Responsible Research		
Title:	Student's knowlede monitoring mode using system dynamics		
IRB ID:	15-195		
Approval Date:	6/5/2015	**Date for Continuing Review:**	6/1/2017
Submission Type:	New	**Review Type:**	Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems** involving risks to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form at least** three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed. For example,** access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

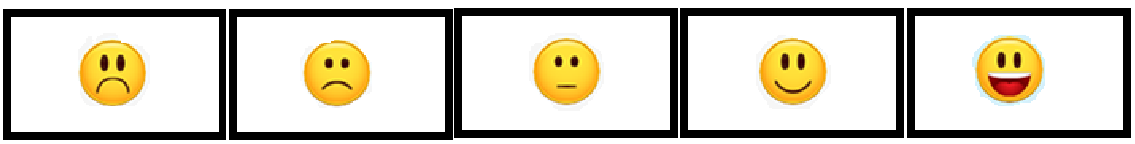
APPENDIX B

DATA COLLECTION FORMS

Student Survey 1: (Once a week- Any class lecture day) **Approx time: 3 minutes**

Please provide your secret student's code ________________

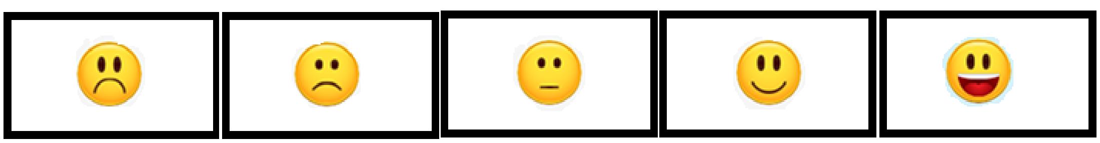
Q1. How determined/focused were you today to study for COMS 227?



(Very upset. Cannot focus at all) (Upset and can focus only to some extent) (Don't know how I feel) (Happy and determined) (Very happy and highly determined)

Other_______________________________________

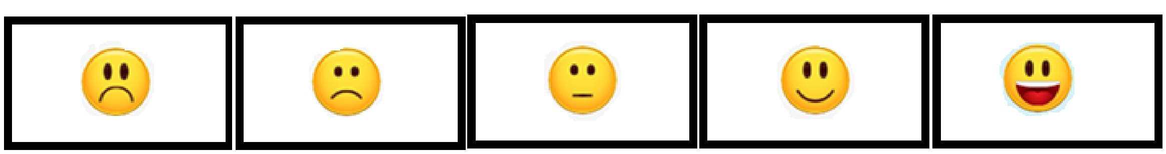
Q.2. How did you feel about going to class session of COMS 227 today?



(I don't feel like attending the class at all) (I don't feel so good Class is not very good) (Don't know how I feel) (I feel good. The class is nice) (I feel very excited to attend the class)

Other_______________________________________

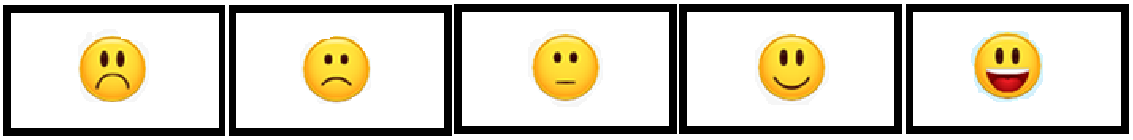
Q.3. How enthusiastic was your teacher today?



(Not at all interested In teaching) (Showed only little enthusiasm) (Don't know how I feel) (Pretty enthusiastic) (Very enthusiastic)

Other_______________________________________

Q.4. How interesting was the topic taught in class today?

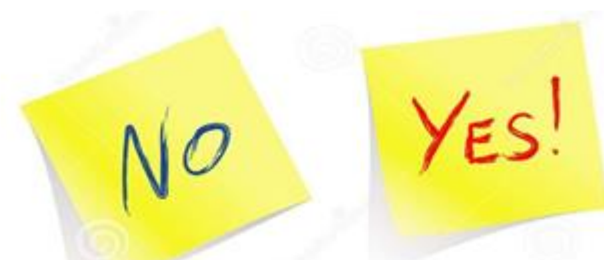


(Very boring) (Little interesting) (Don't know How I feel) (Pretty interesting) (Very interesting)

Q.5. How enthusiastic are you about practicing the topic taught today? (1 being lowest, 5 being highest)

1 2 3 4 5

Q.6. Did you think it was important for you to complete your homework during this week?



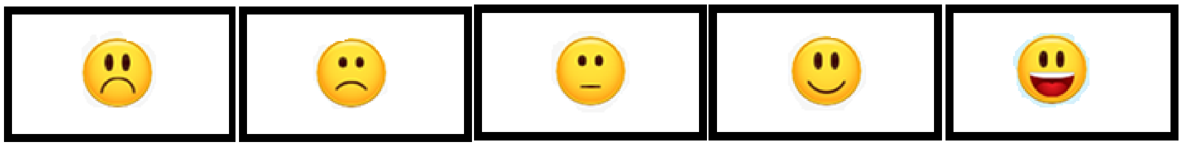
If No, then tell us why you think completing homework was not important:

____

Q.7. Do you think that lack of daily practice made you forget the topics taught in the class for this week?

Any other comments:____

Q.8. How did you feel about learning new things in class during this week?



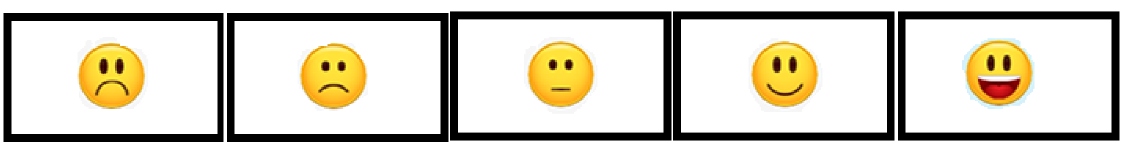
(I am not at all enthusiastic to learn)	(I am not so keen to learn)	(Don't know how I feel)	(I am keen to learn new things)	(I am very enthusiastic to learn)

Other ____

Q.9. During this week, how did bad scores in tests make you feel?

(Very upset with the performance) (Highly motivated to do better the next time)

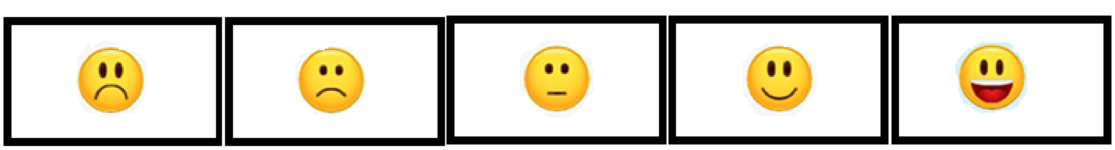
Q.10. How did you feel about your personal life during this week?



(Not at all good. Very upset)	(Not so good)	(Don't know how I feel)	(I was happy & satisfied)	(I was very happy and felt great)

Other______________________________

Q.11. During this week, how did you feel about taking tests?



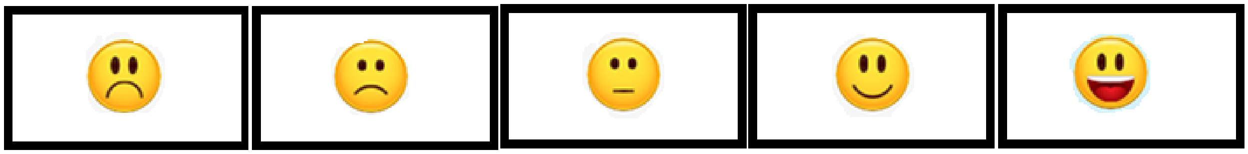
(Very scared. I don't like taking tests at all)	(I am little scared.)	(Don't know how I feel)	(I feel good and motivated to do better)	(Very excited & very motivated to do better)

Other________________________________

Student SURVEY 2: (Once a week- Any lab day) **Approx time: 3 minutes**

Please provide your secret student's code **________________**

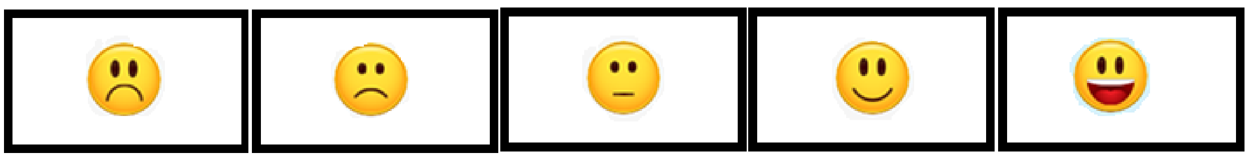
Q1. How determined/focused were you today to study for COMS 227?



(Very upset. Cannot focus at all)	(Upset and can focus only to some extent)	(Don't know how I feel)	(Happy and determined)	(Very happy and highly determined)

Other____________________________________

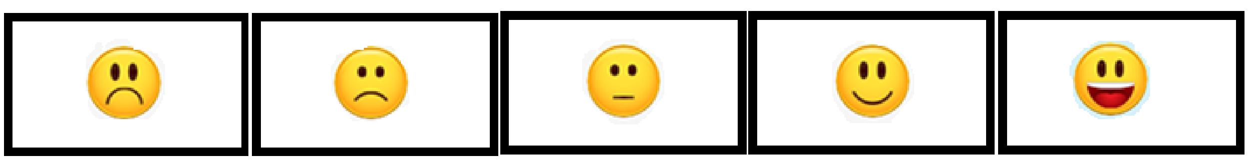
Q.2. How did you feel about attending the class session of COMS 227 today?



(I don't feel like attending the class at all)	(I don't feel so good. Class is not very good)	(Don't know how I feel)	(I feel good. The class is nice)	(I feel very excited to attend the class)

Other____________________________________

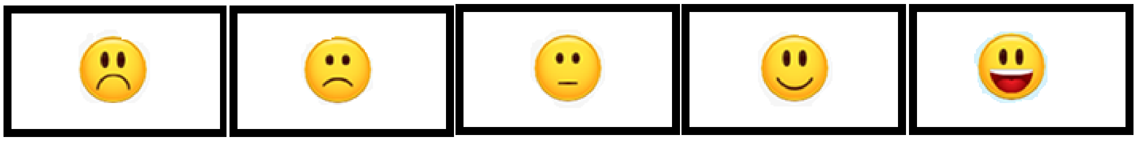
Q.3. How enthusiastic was your teacher today?



(Not at all interested In teaching)	(Showed only little enthusiasm)	(Don't know how I feel)	(Pretty enthusiastic)	(Very enthusiastic)

Other___________________________________

Q.4. How interesting was the topic taught in class today?



(Very boring) (Little interesting) (Don't know How I feel) (Pretty interesting) (Very interesting

Q.5. How enthusiastic are you about practicing the topic taught today? (1 being lowest, 5 being highest)

1 2 3 4 5

Q.6. How satisfied are you with the grading done by the course instructor/teaching assistants for this week? (1 being lowest, 5 being highest)

1 2 3 4 5

Q.7. How do you ensure about the correctness of the homework/assignments for this course? (Examples: I check with the textbook, I go through my answers, I debug my code for any errors, I ask doubts to the instructors, etc.)

____

____

_____

Q.8. During this week, did the instructors/ teaching assistants give you sufficient extra time outside the class to help you?

Yes No Sometimes

If you answered No/Sometimes, tell us how much more time do you need from your instructors/teaching assistants? Please provide with any other comments, if any.

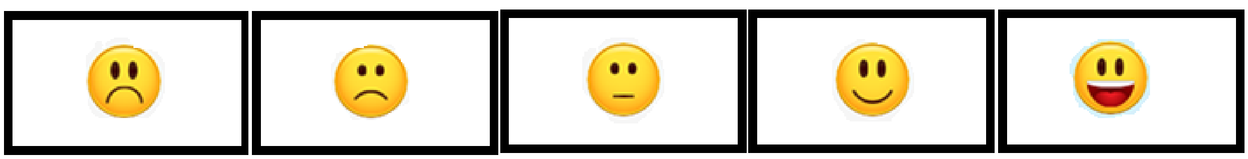
____

___

Q.9. On an average, how many personal issues did you experience in this week? Please just provide an approximate number. (Example: 5 issues/week) Note: No additional questions will be asked for this question.

____

Q.10. How did you feel about the amount of homework given to you in the class for this week?



(It's a lot. I am struggling a lot finishing it.)	(It should be a little less. I struggle with it sometimes)	(Don't know how I feel)	(I am happy and can manage the amount)	(I think it's the right amount. I can easily finish it)

Other___________________________________

Q.11. On an average, how many hours did you spend in studying for COMS227 during this week?

____

Q.12. On an average, how much was the gap between your expected scores and your actual scores for this week?(Example: Your average actual score: 50/100, Your average expected score:85/100. Gap=+35)

____

Student SURVEY 3: (Only once- at the end of the course, after the final tests) Approx time: 4 minutes

Please provide your secret student's code ________________

Q.1. What do you like the most about your class?

Q.2. What do you dislike the most about your class?

Q.3. How useful do you think this class is/will be for you in your daily/future life? (1 being lowest, 5 being highest)

1 2 3 4 5

Give us some examples if you think it's important:

Q.4. Do you think working in groups helps you learn better about the course?

Q.5. What do you like to do in your free time? (Example: playing football, painting, video games etc.)

Q.6. Are you currently working or planning to work on some projects which utilizes/will utilize the concepts taught in COMS 227? If yes, just give the number of projects which you plan/are working. (Example: currently working: 1, plan to work: 1)

____

Q.7. Out of all courses pursued so far, which course do you like the most? Provide the name/names of the course/courses.

____

____

Q.8. Do you prefer completing your homework/assignments on your own or you prefer working in groups?

____

Q.9. How do your parents support you when you get bad scores in tests? (Example: They motivate me to do better, help in my studies)

____

____

Q.10. What motivated you to choose your current academic field? (Example: I was always fascinated with computers and playing games. I wanted to contribute in this area.)

____

____

____

Teacher Survey 1: (Once a week- any class lecture day) **Approx time: 3 minutes**

Please provide your secret teacher's code ________________

Q.1. How enthusiastic were your students today? (1 being lowest, 5 being highest)

1 2 3 4 5

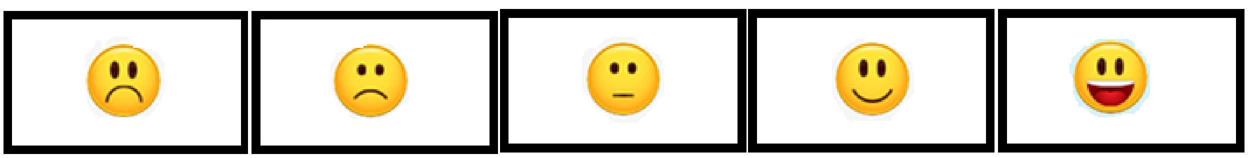
Q.2 How difficult was it for the students to understand the topic today?

1 2 3 4 5

Q.3. On an average, how did the class participate today? Please provide an average number of questions asked by the students or responses given by the class. (Example: average no. of questions asked: 5, average no. of responses given: 2. Total: 7/day)

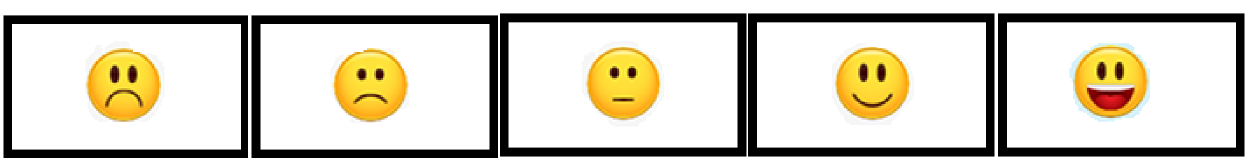
____

Q.4. How do you feel about your today's performance as a teacher?



(Not at all good. Very upset)	(Not so good)	(Don't know how I feel)	(I am happy & satisfied)	(I am very happy and feel great)

Q.5. How did you feel about your personal life during this week?



(Not at all good. Very upset)	(Not so good)	(Don't know how I felt)	(I was happy & satisfied)	(I was very happy and felt great)

Other______________________

Q.6. On an average, how much time did the students take to understand correctly a difficult topic during this week?

A. One class   B. Two classes   C. Three or more classes   D. Do not want to understand at all

Q.7. According to you, what are some challenges which your students are facing in the class during this week?

____

___

Q.8. During this week, how much time did you dedicate towards your teaching profession outside college hours per week? (For example: Around 2 hrs/week in learning about new teaching methodology, improving on existing teaching methodology, etc.)

____

Teacher SURVEY 2: (Once a week-any lab day)   Approx time: 3 minutes

Please provide your secret teacher's code ________________

Q.1. How enthusiastic were your students today? (1 being lowest, 5 being highest)

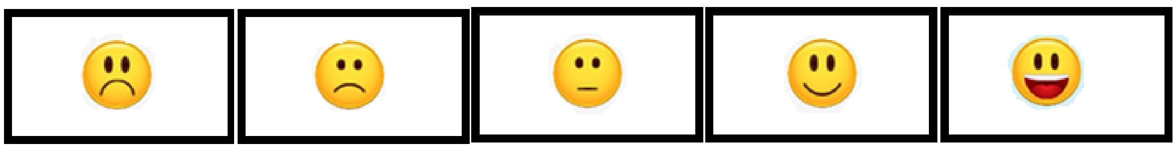
1   2   3   4   5

Q.2 How difficult was it for the students to understand the topic taught today?

1   2   3   4   5

Q.3. On an average, how did the class participate today? Please provide an average number of questions asked by the students or responses given by the class. (Example: average no. of questions asked: 5, average no. of answers give: 2. Total: 7/day)

Q.4. How do you feel about your today's performance as a teacher?



(Not at all good. Very upset) | (Not so good) | (Don't know how I feel) | (I am happy & satisfied) | (I am very happy and feel great)

Q.5. What did you do to improve the performance of the low scorers of the class in this week?

Q.6. On an average, how many personal issues did you experience this week? Please just give the number. (Example: 5 issues/week) Note: No additional questions will be asked for this question.

Q.7. How did you motivate your students to participate more in the class during this week?

Q.8. During this week, did you ever feel like quitting from your profession due to lack of support from students or from the university?

____

____

Q.9. During this week, did you feel demotivated when you saw your students disinterested, or did you work on improving their motivation?

____

____

Teacher SURVEY 3: (Only once- at the end of the course, after the final tests)

Approx time: 1 minute

Please provide your secret teacher's code ________________

Q.1. Are you satisfied with the paycheck you get to teach the students of COMS227?

Yes | No | Money is not important.

Other comments, if any:____

Q.2. What motivated you to become a teacher?

____

____

Q.3. What do you like to do in your free time? (Example: painting, travelling, etc.)

____

____

APPENDIX C

GQM FOR STUDENTS' GROWTH MONITORING MODEL

Our success measures are based on the GQM approach, using the following goals:

Goal	**Question(s)**	**Metric(s)**
Improve students' understanding of the course	How have students' scores improved during the course duration? How did students respond to the teaching techniques used in the class? What methods helped the students to improve their understanding?	Students' scores on assignments, labs and tests throughout the course. Feedbacks about the teaching styles, teachers' enthusiasm and topic interest, challenges faced. Amount of students' practice time and amount of extra time provided by the teachers
Improve the personality of the students and their outlook towards facing challenges	What was the average participation rate of the class? What was the students' level of determination after facing failures? How satisfied are the students with their tests scores?	Rate of number of students participating per class day. Test anxiety level of the class and their scores on subsequent assignments, labs and tests. Analysis of Performance gap in the tests.
Increase course interest among the students	How much course related extra work is the student doing? How much research/non course related work is the student doing? How much information do the students extract from the teachers?	Amount of practice time provided by the students for the course. Number of projects taken by the students involving course related knowledge. Amount of extra time provided by the teachers. Rate of number of students participating per class day.
Improve student enthusiasm to attend the class	What is the percentage of student's attendance in the class? How do the students feel about attending the class?	Percentage of students attending the class session per week. Feedbacks about teachers' enthusiasm, teaching

	How are the students affected by their personal life? How satisfied are the students with their tests scores?	method, topic interest, students' motivation level. Rate of number of personal issues experienced per week by the students Analysis of Performance gap in the tests. Feedbacks on teachers' grading technique.