Modern Electronics: Teaching Economics to High School Students with a System Dynamics Simulator

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Abstract

Economics is often a difficult subject for students to learn because it is taught in an abstract manner. This paper describes a simulator that teaches students economics in terms of a familiar economic institution, the retail store. The simulator casts the economics of a store within a System Dynamics framework. This enables students to understand the importance of feedback relationships in determining economic performance and viability of a business. An SD framework also enables them to understand the relationships among concepts such as demand, price, service quality, and the range of merchandise offered and available and how they change over time in relation to each other. The paper displays screens that the students use to enter decisions and track the store's performance through a number of simulations. Teaching economics with a simulator can actively engage students and help them learn more effectively as well as having some fun.

Key Words: economics, K-12 education, simulators, interactive learning environment, retail management

Introduction

Teaching economics effectively to high school students requires that the subject be made real to them. This shouldn't be difficult since they are surrounded by economics in their everyday lives. They are constantly making economic choices as they buy goods and services. They operate the equivalent of small businesses in activities that raise funds for clubs. Yet economics is often taught as a dry, analytical subject that is difficult for them to relate to everyday life.

This paper describes a simulator based on a System Dynamics model of a small retail business called "Modern Electronics". This type of business is one that is familiar to high school students, selling small consumer electronics items such as CD players that most students own. Being able to "run" this business can make economics much more real for students. It can also motivate them by engaging their competitive spirit to see who can run the business most effectively.

There is a long history of using management simulators to teach System Dynamics and Systems Thinking. Senge and Lannon describe the value of simulators or "microworlds"

as tools for organizational learning. Certain simulators such as People Express have had extensive use for general management training and have been studied by Sterman for their effect on learning. Simulators have been developed in specific fields such as health care to help those in the field understand the implications of major changes (see Hirsch and Immediato, Hirsch and Kemeny). Particular design issues such as the desired degree of transparency in simulators have been studied by Grossler and by Machuca et al. Topics covered by the retail simulator being presented have also received extensive treatment in the System Dynamics literature. These include the logistics of supply chains (see for example Barlas and Aksogan; Ulegin et al).

Expanding on Traditional Economics

Basing the simulator on a System Dynamics model also makes it possible to expand on the traditional ways in which economics is taught, making it easier for students to relate what they are learning to real world experience. For example, economics typically focuses on price as the determinant of demand for goods. However, students know that price isn't the only thing that will affect their choices when they go into a store. The average level of prices in a store is only one criterion. The range of choices for different products, models, and features is another. Having enough salespeople who are knowledgeable about the products is third factor. Advertising also affects where they shop and what they buy. Figure 1 shows the beginning of a tutorial that introduces students to the simulation game and to the broader set of determinants of demand on which it is based. Each factor is explained in terms students understand. Students are shown how each of these factors can be affected by decisions available to them. For example, they learn that Service Quality reflects the ratio of customer visits to staff available and can be affected by the hiring rate they set and the salary they pay to employees.

Students also learn that certain decisions will have consequences beyond the immediate intended ones that they had better be aware of. Figure 2 shows how decisions about the Range of Merchandise to offer will affect the size of the inventory required. The inventory available, in turn, affects the store's ability to retain customers. If customers come to the store and cannot find what they want, they will stop coming. The implication is clear: offering a wide range of merchandise isn't helpful if a store cannot keep enough inventory in stock. Students continue through this tutorial and, as shown in Figure 3, learn how the decisions they make affect the financial performance of the store and their ability to make a profit and stay in business.

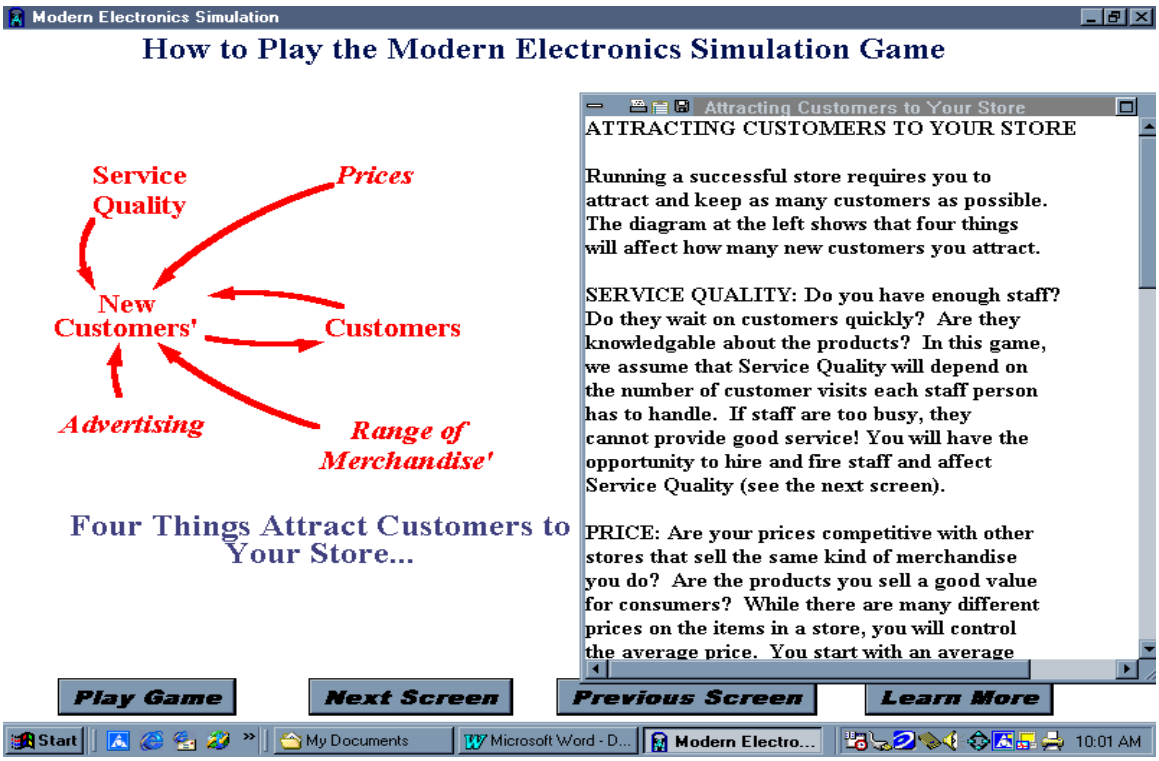

Figure 1: Introduction to Determinants of Demand

Figure 2: Effect of Range of Merchandise on Required Inventory and Customer Retention

Figure 3: Financial Consequences of Decisions

Playing the Game

Once students have been through the tutorial (or without it if they would just like to plunge in), they make decisions and move through a two year (104 week) simulation in thirteen week (one quarter) intervals. They are able to revise decisions each quarter in response to the performance that the store displays. Figure 4 shows the overview screen that they work from. The causal diagram provides a context for both the decisions they make and the results they observe. They're able to trace the causes of poor performance from one variable to the next.

The graphs in Figure 4 reflect a simulation with the default values for all of the decisions. $1,000 per week is spent on Advertising. The average Price of the items sold is $100, about the middle of the pack in the local market. Similarly, the Range of Merchandise offered is set at 50, a middle of the road value. The results are not very impressive. The store is able to attract only a small number of customers. Service Quality remains high simply because the staff has few customers to serve. The store eventually runs out of Cash and cannot reorder Inventory. The few Customers who do come can't find what they want and so there are fewer sales as a result of the low Availability effect. This discouraging result presents a challenge to students. What should we try next?

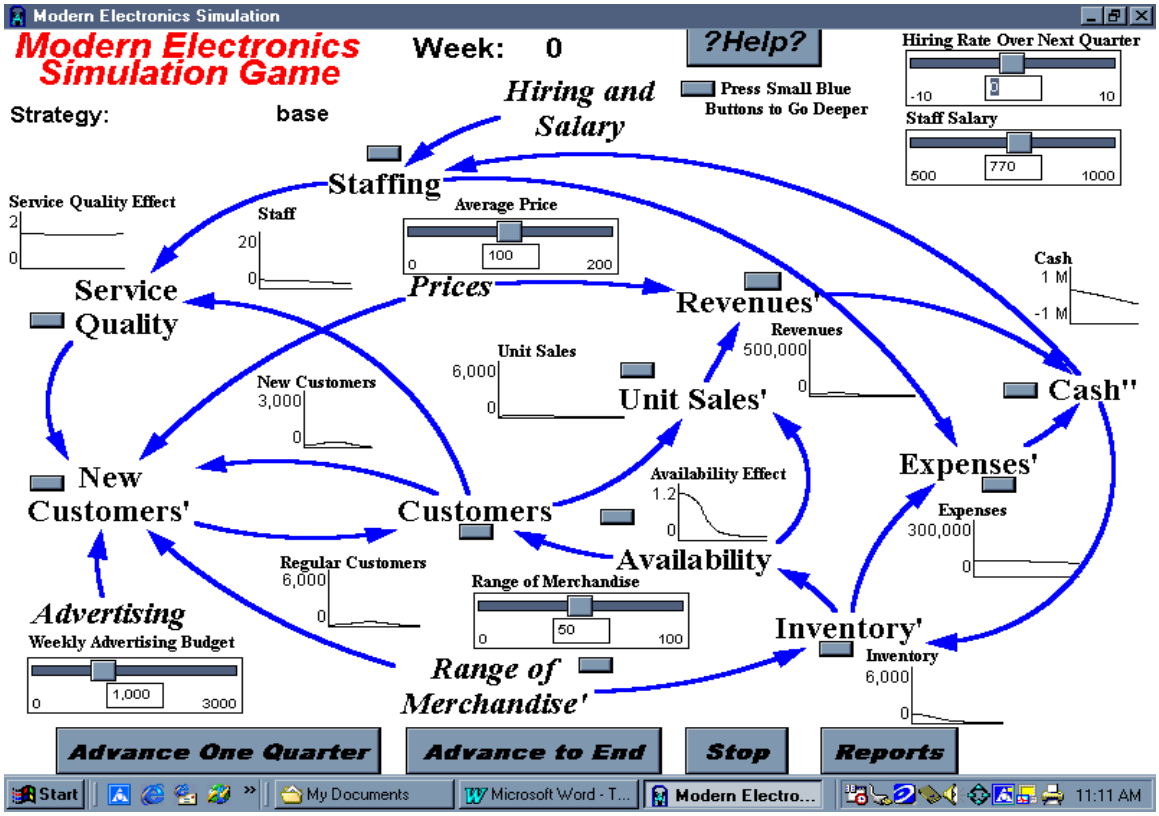

Figure 4: Overview Screen with Decisions and Results from Default Simulation

Economic theory suggests that price is important and that lowering prices will bring more customers into the store. Students' own experience is that they prefer to buy things on sale. Let's try lowering the price to $80 from $100 and observe the results. The results look almost identical to the graphs in Figure 4. How could this be? Using the small blue buttons on the overview screen let's us "drill down" to understand what is going on in more detail and also get to graphs that compare the values of key variables across several simulations. Pressing the button next to Customers leads to a graph shown in Figure 5 that compares numbers of customers in the low price simulation with the base run. The graphs show that the lower prices were, in fact, successful in bringing more customers to the store. However, the strategy ultimately failed because each sale at the lower price was not generating enough money to cover the cost of the sale. The level of cash in the bank was depleted, new stock couldn't be ordered, and lack of availability of stock made the store unattractive to customers despite the lower prices.

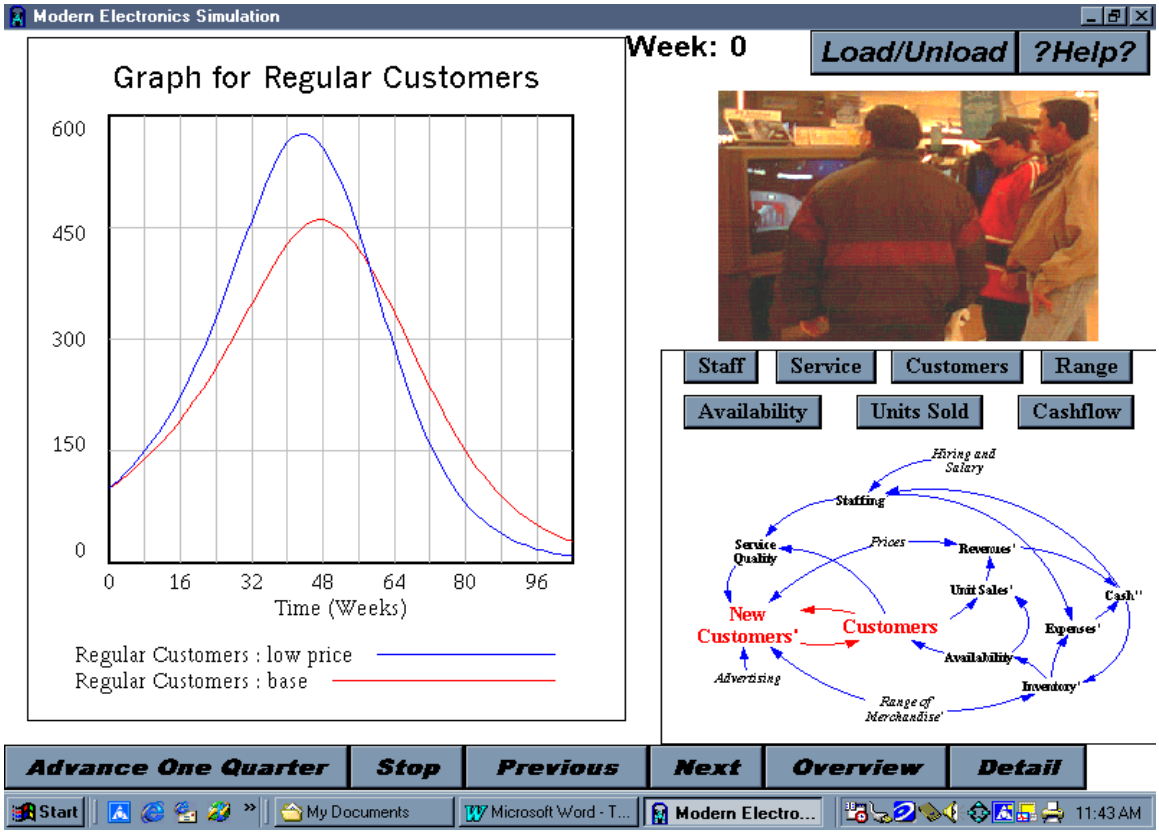

Figure 5: Customers Attracted with Lower Prices Compared to Base

How would students know that they are losing money on each sale? There is additional information in different formats that they can access to understand better what is going on. Figure 6 shows financial reports in more traditional formats including the standard profit and loss statement. Having information in different formats can be valuable to support students with different learning styles. It's also useful to have information in a format that students can relate to other things they are studying such as accounting or small business management. The report in the right-hand column clearly shows that the cost of each unit sold is $947 when all costs of staff and other overhead are taken into account and divided by the very low volume of business that results from the lack of available inventory. With such information, it becomes clear that simply lowering price does not create a viable business.

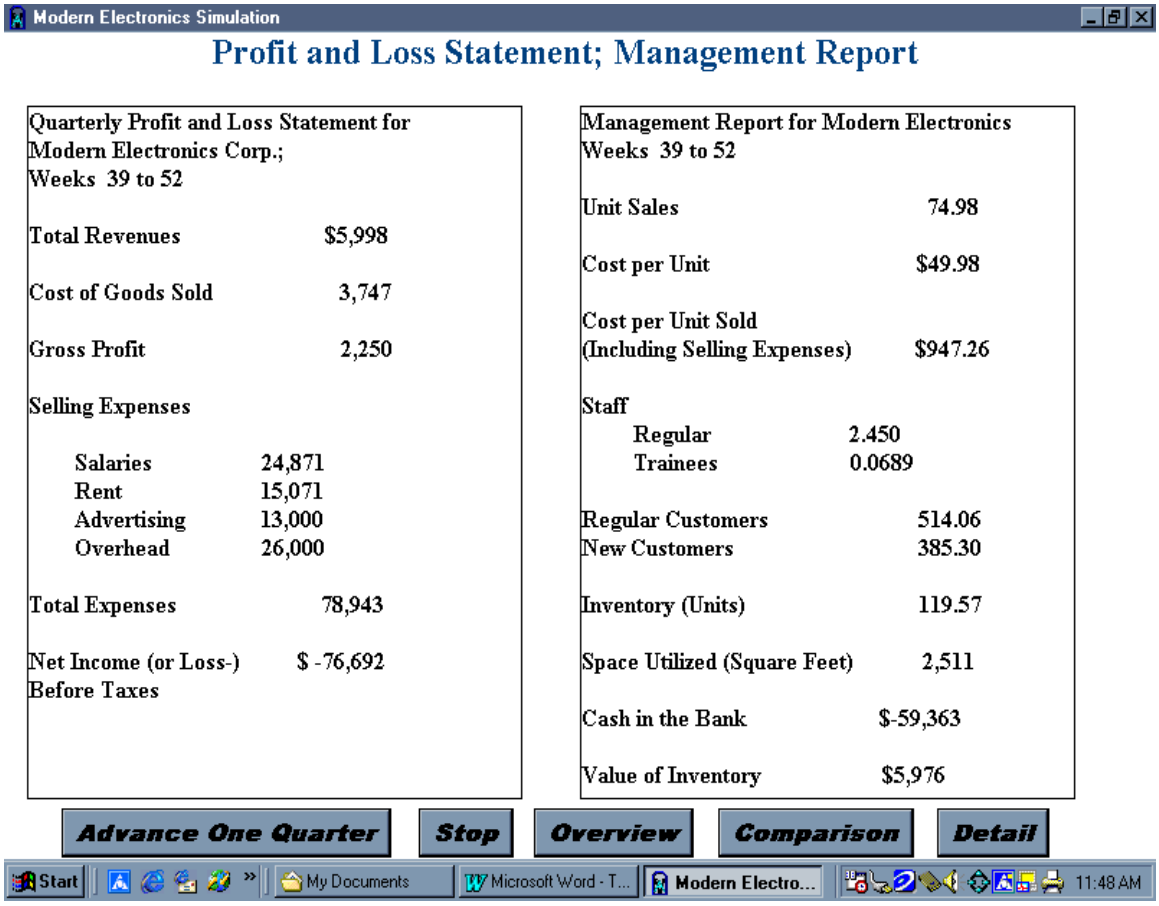

Figure 6: Management Report Showing Cost per Unit Sold

What to try next? Most students would appreciate the value of having a wide range of different products, styles, and features available to them and a natural next step would be to try to expand the Range of Merchandise since lowering prices was not a viable strategy. The next simulation leaves Price at $100, but increases the Range of Merchandise to 100, the high end of the scale reflecting a very wide variety of choices for the consumer. Figure 7 shows how the overview screen would look at the end of this simulation. The difference is obvious from a quick glance. Numbers of New Customers rise quickly and Regular Customers, the people who come back time and again, go up into the thousands. The availability effect goes down initially, but the store is making enough money on its sales to replace inventory and availability stabilizes at a reasonably high level. This is especially significant since the high Range of Merchandise requires a large inventory to back it up.

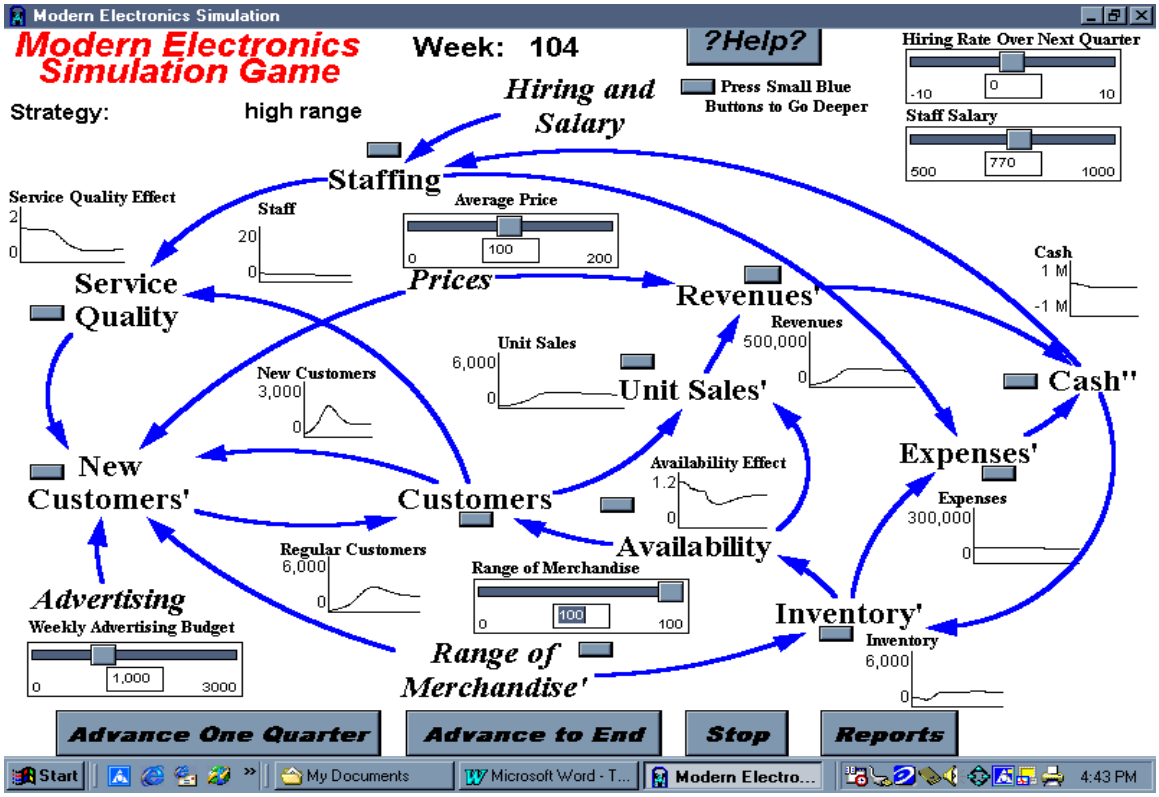

Figure 7: Overview of Simulation with Expanded Range of Merchandise

However, the store has "hit the wall" despite a good start. The number of Regular Customers has peaked and then declined a bit. Unit Sales have leveled off. Cash has declined, leveling off, but not recovering. What happened? The graph for Service Quality reveals much of the problem. Focusing on Range of Merchandise, we neglected to hire the staff needed to deal with the large volume of customers attracted by the expanded range of choices. Staffing is especially important as the range increases because the staff requires more time per customer to explain all of the choices. Not having enough staff causes perceived Service Quality to go down and discourages people who might have become Regular Customers.

This barrier created by Service Quality suggests a need to do some hiring the next time around. In the next simulation we keep the Range of Merchandise at 100 and the price at $100 and begin hiring three people per quarter (one a month) when the Service Quality Effect starts to go down. Figure 8 shows how this strategy deals effectively with the Service Quality problem, helping it to recover once hiring begins, but is a dismal failure by the end of two years as the business runs out of money to purchase new inventory and the availability effect plummets.

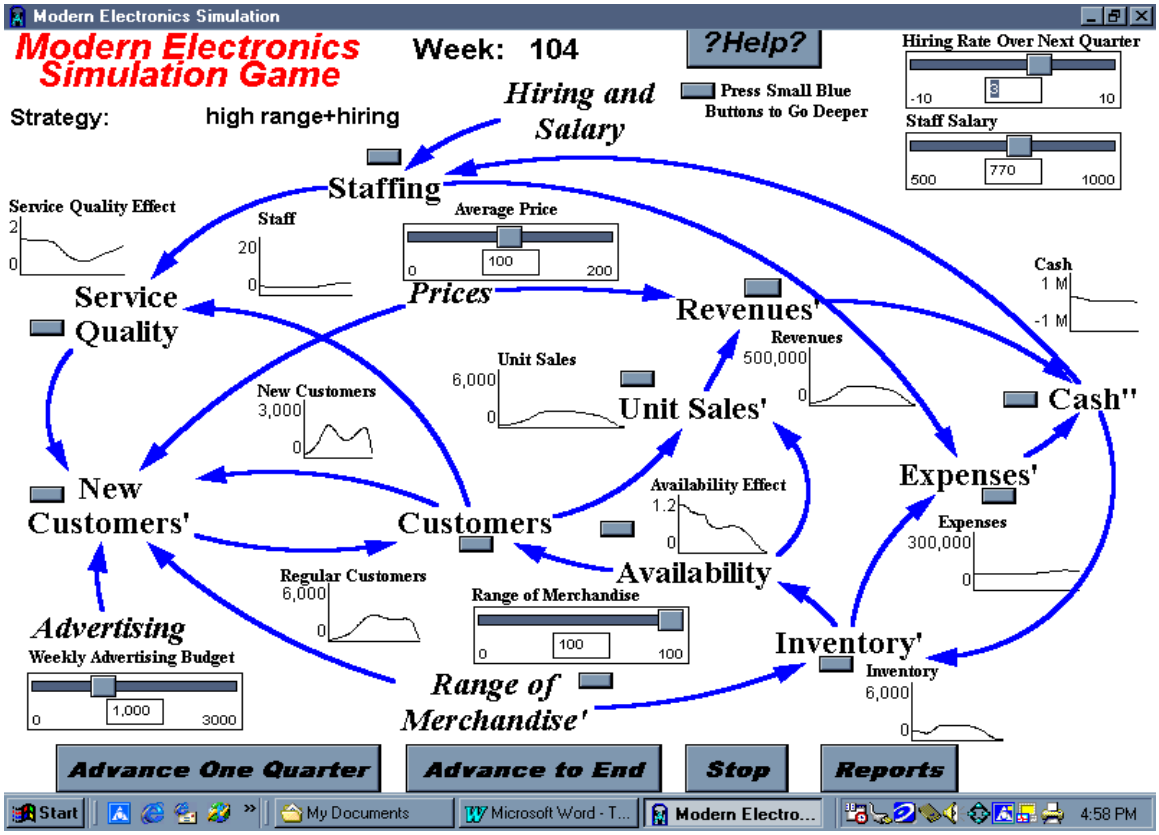

Figure 8: Overview of Simulation Adding Hiring to Expanded Range of Merchandise

Why does this happen? The business is not generating sufficient margins to cover the additional salaries of the staff that are hired. While customers are happier and the number of new customers recovers for a little while, money is lost on each sale, Cash declines, and there is not enough money left to buy new inventory. Regular Customers stop coming when availability drops, making the financial picture even worse.

How could we increase margins? Cutting expenses is one way. Perhaps we could pay salespeople less? By looking at the detailed structure around staffing, shown in Figure 9, the students might figure out that this is not a good idea since lower salaries lead to higher turnover. Staff who leave need to be replaced by trainees who are less productive and make a smaller contribution to Service Quality. Cutting other expenses may be possible, but another way to increase margins is to raise prices and increase the revenue per sale. This seems counterintuitive since higher prices might be expected to discourage customers. What will happen?

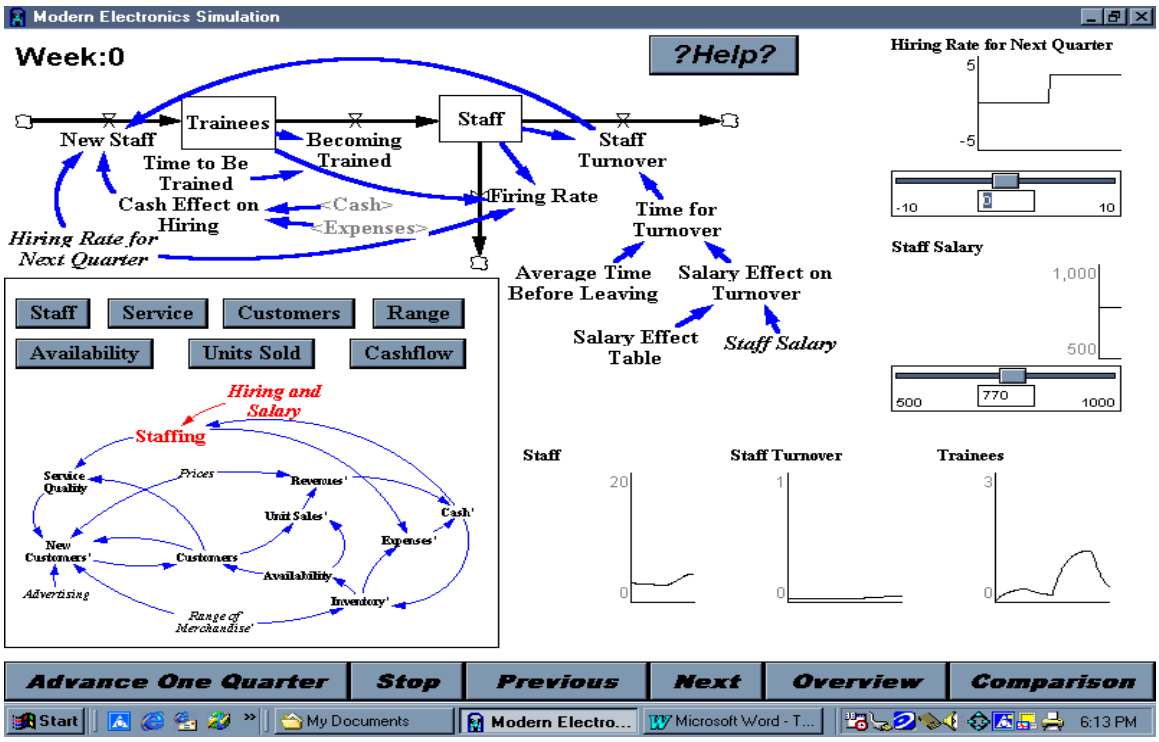

Figure 9: Detailed Structure Around Staffing

The next simulation raises Price to $120 while keeping Range of Merchandise at 100 and hiring three staff per quarter as Service Quality begins to drop. The results are dramatic as seen in Figure 10 on the next page.

This time, the higher Price yields enough margin per unit sold to make each sale profitable and add to cash. After a brief decline, Cash begins to grow. Higher levels of Cash make it possible to hire more staff and maintain higher Service Quality. The rate of New Customers and level of Regular Customers both grow steeply. More cash available also makes it possible to replenish Inventory, keep Availability high, and retain Regular Customers who count on the store having items in stock. Higher numbers of customers and Unit Sales generate more revenues and cash.

Students could do other experiments to improve these results or expand on their options for creating strategies. For example, they could examine whether spending more on Advertising would cause partially successful strategies to succeed or create a new set of problems. The students could also "torture test" strategies by changing some of the basic assumptions and determining whether a good strategy would continue to be successful. This would help them understand that the best strategies are resilient ones that work well under a variety of circumstances rather than depending on conditions to be just right. Figure 11 shows a screen that students can use to change assumptions and do this sort of sensitivity analysis that will help them better understand the system they are working with. They can change assumptions about the external environment such as the size of the market, economic conditions, and the amount of money they are able to get from

investors. They can also change relationships internal to the business such as the length of a customer visit or the likelihood that a visit by a regular customer will result in a sale.

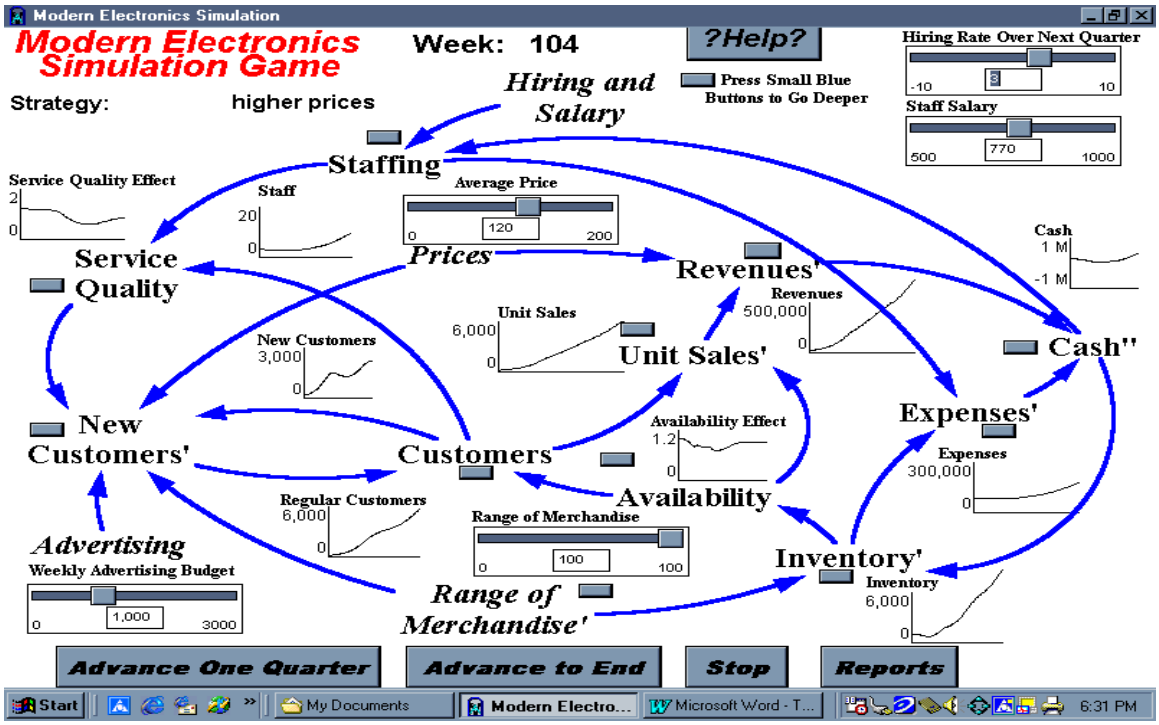

Figure 10: Results of Simulation with Higher Price in Addition to Expanded Range of Merchandise and Hiring

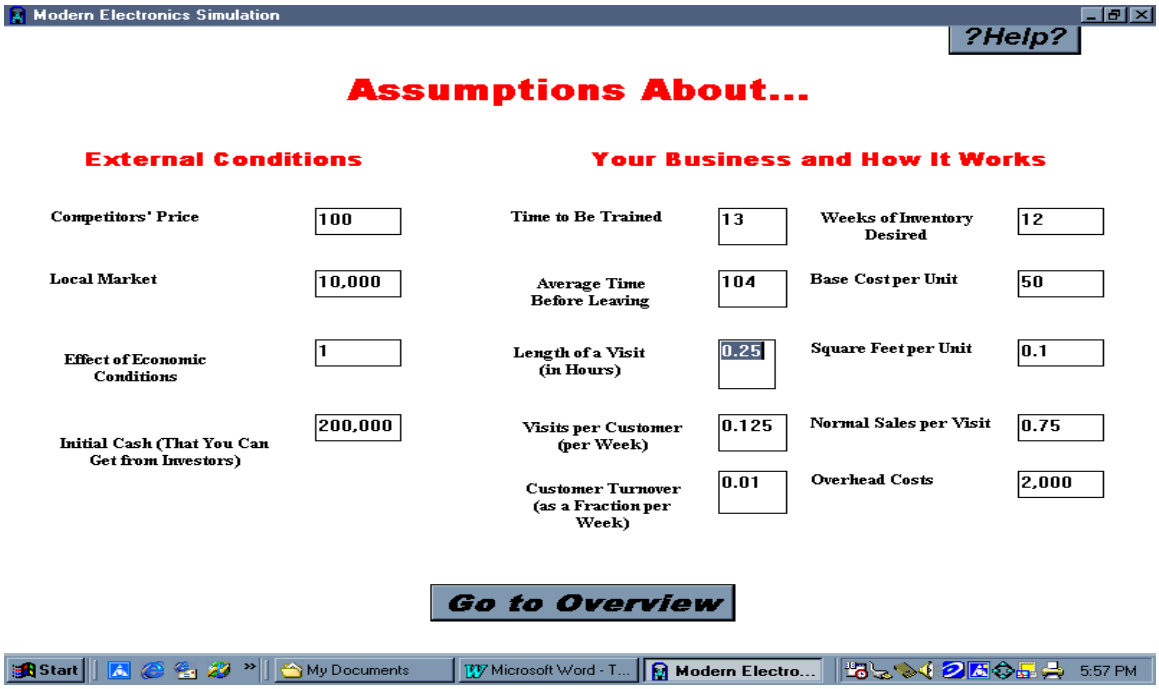

Figure 11: Screen for Changing Assumptions for Sensitivity Analysis

Figure 12 shows what would happen if a student tried testing the successful strategy with higher Price and high Range of Service by lowering the assumed Competitors' Price from $100 to $80. This might reflect a new competitor with "deep pockets" (or one who is able to get a lower wholesale price or have lower selling expenses) entering the community and charging a low price for an extended period of time. Will the previously successful strategy still work? The results shown in Figure 12 indicate that the price difference is now too great and our store is not able to attract a sufficient volume of business, even with its greater Range of Merchandise. Service Quality never becomes a problem since Unit Sales top out at a low level. These results suggest that strategies successful under certain circumstances may not be effective if conditions change.

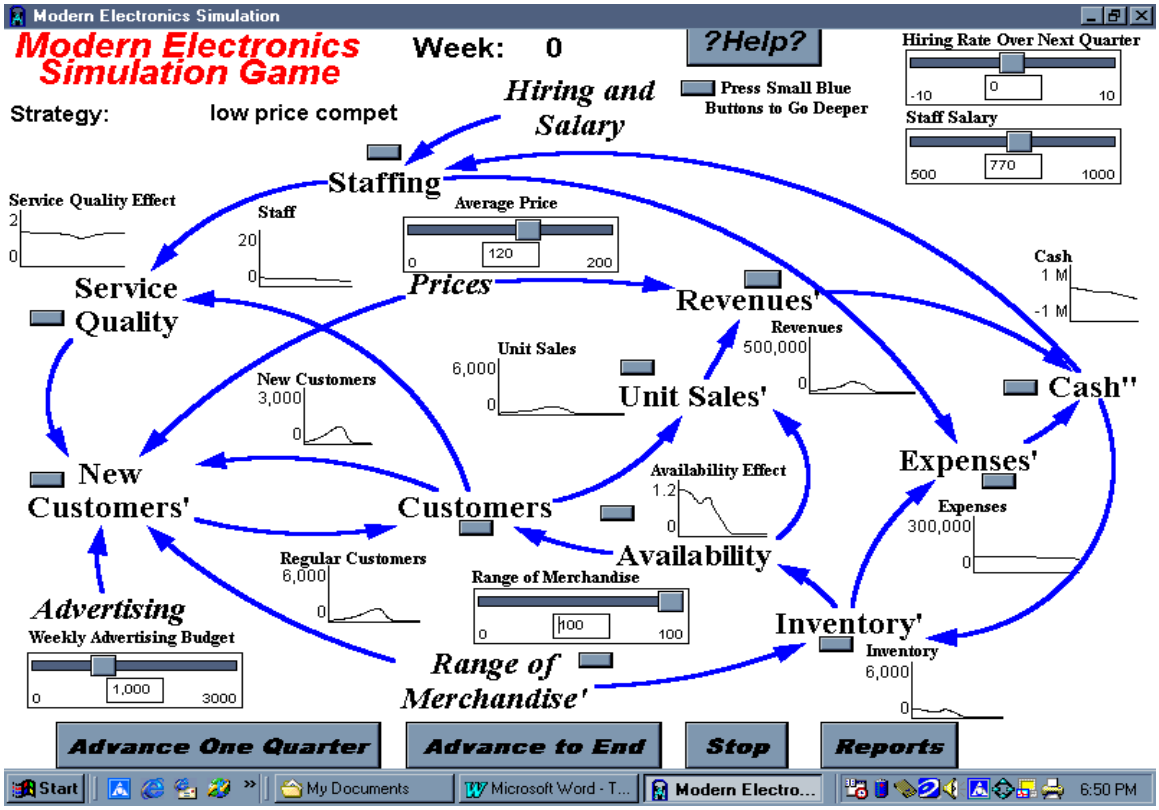

Figure 12: Results of Raising Assumed Competitors' Price in Simulation with Higher Price in Addition to Expanded Range of Merchandise and Hiring

Discussion

What do students learn from doing experiments such as these with the simulator?

- First of all, they come to understand that economics is about more than price. It is about the many features that come into play as people make buying decisions.

- They also learn that while it is important to understand each factor separately, the various factors affecting the profitability of a firm interact with each other over time.

A strategy for running a business must deal with multiple factors. Simple-minded strategies (e.g., "We'll be the price leader!") generally are not successful.

- It also becomes clear that actions taken at one point in time will affect options at a later point in time. For example, a price that is set too low will doom a firm regardless of how much business volume it can generate. The theory of the firm, as it is typically taught in economics, concentrates on the conditions facing the firm at each point in time. System Dynamics enables students to understand the effects of decisions over time and how decisions made at one point in time will affect the conditions the firm faces at a later point.

The simulator could be used at any of several different points in an economics course. It could be used, for example, to help students better understand the concept of demand and how demand changes based on multiple factors. It could also be used to teach how supply is dependent on the resources available to the firm such as cash and inventory which, in turn, depend on past decisions. In each case, the simulator can help students integrate the concepts they are learning and to "put them into motion" in a manner that economics curricula often do not allow. It's possible to create a curriculum around the simulator and use it multiple times to help teach different economic topics.

The simulator can help students and their teachers get a deeper understanding of many of the key topics in economics. They can understand, for example, how demand falls as Price increases (all other things being equal) and how it also falls as Service Quality decreases. More importantly, they can also understand why charging a higher price is sometimes essential for creating a viable business and offering the various amenities that also attract customers. This is something they wouldn't learn by focusing on price alone and need to consider its interaction with other variables.

This simulator can also be quite useful for teaching System Dynamics. Students can see graphically how reinforcing loops through Regular Customers, Unit Sales, Revenues, Cash, Staffing, Service Quality, and New Customers and through Cash, Inventory, Availability, and Regular Customers can work to accelerate growth if the conditions are right or put the firm into a tailspin if things go wrong. They can also see how balancing loops through Regular Customers, Service Quality, and New Customers and through Cash, Inventory, and Expenses can resist growth and tip growth into a downturn very quickly. The interface design lets them bring structure and behavior together.

Next Steps

The simulator can benefit from further development in several areas. For example, as shown in Figure 11, students can change constants to explore the sensitivity of the system to different parameters. An enhancement would be to also let them choose different curves that represent relationships between factors such as Price and attraction of New Customers that reflect their own preferences or to develop new curves based on their preferences.

The simulator has so far had only limited testing. The next step would be to evaluate it in the context of regular high school economics or small business management courses to determine whether it helps students develop a better understanding of economic concepts. There are economics standards and benchmarks that can provide a framework for evaluating the impact of the simulator. For example, Standard 14 offered by the National Council on Economics Education in the US indicates that students should develop the following understanding:

Entrepreneurs are people who take the risks of organizing productive resources to make goods and services. Profit is an important incentive that leads entrepreneurs to accept the risks of business failure.

Experience with the simulator should help students understand the difficulty of successful entrepreneurship and appreciate the value of clearly thought out strategies for running a small business.

Additional simulators of this sort can be developed to teach other economic concepts. The author has already worked with two teachers at a Middle School to develop a simulator that puts students in charge of running a community newspaper. Using the simulator, they learn how the interplay of staffing, pricing, and content decisions affect the newspaper's ability to boost its circulation, sell advertising space, and make a profit. Other types of businesses such as manufacturing companies can be the subject of simulators. Markets where teams of students compete with each other would make exciting and informative simulations, especially if the simulator provides enough information for students to understand why the successful firms win.

Simple simulators can also be developed to teach students about regional and National economies. While these economies are quite complex, simplified versions can help students understand, for example, how several key factors interact to affect a region's attractiveness and cause some regions to do well while others stagnate. Simulators can also be developed around critical economic issues such as poverty and unemployment and difficulty achieving economic progress in developing countries. The essential ingredients to make any of these simulators effective teaching tools are:

- A series of screens that introduce the economic concepts in a System Dynamics framework, identifying the key feedback loops,

- A manageable number of decisions for students to use for structuring experiments, and

- Having information provided in formats such as those used by the Retail Simulator that make it possible to relate system structure, various strategies and policies, and the resulting behavior and economic performance.

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