Research Experiences for Teachers (RET) 2004
Use of Computer Simulation Games for Instructional Purposes in Middle School and Jr. High

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Summary

The 2004 Summer RET program at the University of Arkansas provided an opportunity for two public school teachers to conduct research in the area of designing and managing supply chains, as well as in basic industrial and systems engineering. Emphasis was placed on how these concepts can be explored through the use of a simulation game that would provide a high interest classroom project based upon sound curriculum. The challenge for the project was to create an activity involving a simulation-based video game relating to a particular aspect of Industrial Engineering. The activity was to then be used as a laboratory exercise for INEG 1103: Principles of Industrial Engineering and also modified for use as a classroom activity for junior high school students. Obviously, a major issue was designing the activity with a proper level of difficulty for both age groups while keeping the subject matter relevant to meaningful engineering and junior high instruction.

The materials developed are intended to help students acquire fundamental problem solving capabilities as well as a basic understanding of some tools used in Industrial Engineering and logistics. This project was completed under the leadership of two mentoring professors: Dr. Richard Cassady and Dr. Ed Pohl, who provided guidance and also secured funding necessary to support the implementation of the curriculum into the public schools by providing the necessary supplies through the support of Dr. John English, center director at the University of Arkansas.

Background Research

Our research was aimed at gaining a basic understanding of engineering logistics and the management of supply chains and maintenance. This background knowledge was acquired through the textbooks, *Introduction to Industrial and Systems Engineering and Designing and Managing the Supply Chain,* as well as other related research articles which are listed in the bibliography. Related articles on the use of simulation games for educational purposes were also an important source of information. Games represent a performance-based environment. One cannot be passive when playing a game. "Learning through performance requires active discovery, analysis, interpretation, problem-solving, memory and physical activity which results in the sort of extensive cognitive processing that deeply roots learning in a well-developed neural network"[1] This addresses typical industrial and systems engineering primarily in production

operations. Through the use of simulation computer games, students can take a constructive approach towards several engineering concepts such as analyzing proposed products or services, improving existing products and services, determining the best facility layout, and performing operation scheduling.

Dr. Richard Cassady and Dr. Ed Pohl, Industrial Engineering, were the mentoring instructors involved in the program. They provided information regarding past projects using simulation games and also assisted in making connections to the course syllabus for INEG 1103: Principles of Industrial Engineering. Independent reading of related articles was also helpful in understanding the scope of the project as well as how industrial engineering concepts relate to simulation-based video games.

Simulation games have become a significant part of the video game industry in recent times. Some thought has been turned towards harnessing the intrinsic appeal of these games for educational purposes. This RET project was intended to tap into that appeal to create a lab activity that would be meaningful, motivating, and engaging. Paul Starr, Professor of Sociology at Princeton University and co-editor of *The American Prospect*, says this of simulation-based video games

> "And with the advent of multimedia, the computer has evolved into a distinctive medium that is uniquely capable of juxtaposing text, images, audio, and video. Multimedia permits an extraordinary flexibility in conveying concepts—through words, pictures, and sounds, as something that can be built or played as well as read or watched. . . . New genres, such as simulation games, are emerging that challenge the user or player to build some complex creation—a city, species, business, or world—out of some given set of resources, or that put the student into a simulated environment or through a scenario to meet a challenge or learn a skill. The computer thereby turns the passive reader into a participant; it cues the student of a need to do something, but not necessarily what to do. With multimedia the computer draws on more of the senses, and more dimensions of intelligence, enlarging the opportunity to learn for those who have been less able to learn from conventional teaching materials. . . . [S]ome uses of the new media are genuinely inspired, provocative, and engaging, and these examples suggest that that we have opened an important new chapter in the history of the imagination—and of education."[2]

Time was also devoted to researching specific simulation-based games. The selected games needed to have high interest levels and involve a problem-solving mentality that could be related to an introductory level engineering process.

Project Description

Since we worked with two different age ranges of students, we chose two separate simulation video games: Roller Coaster Tycoon 2 for the eighth grade students and Zoo Tycoon Complete for the sixth grade students.

Roller Coaster Tycoon 2 (RCT2) is a computer-based interactive video game that was considered to have a high interest level for the targeted age groups. Two industrial engineering topics were selected that had the potential to meet the requirements of the project. The topics were a *Cause-and-Effect Diagram* and queuing theory.
The first selected topic was a problem-solving strategy called a *Cause-and-Effect Diagram.* "The cause-and effect diagram is also known as a *fishbone diagram* or an *Ishikawa diagram*. It is used to summarize knowledge about possible causes of variation or some other problem. It organizes the causes of variation or the causes of a quality problem into logical categories. It helps a team focus on different possible causes and is therefore a valuable tool for organizing efforts to improve a process."[3] The cause-and-effect diagram activity was modified to provide relevance to both age groups by providing extra guidance and details to the junior high students.

The second selected topic was intended to provide a higher level activity for the INEG 1103 laboratory. The waiting or "queue" lines in the theme park were a natural opportunity to investigate queuing theory. Much time is spent waiting in line at theme parks. Can the queue for a ride in RCT2 be modeled as an M/M/1 queue? An M/M/1 queue assumes Poisson distributed arrivals and exponential service times.

RCT2 is a strategy-type video game that has been popular for a couple of years. The player builds, operates, and manages an amusement park. Each park is unique according to the player's decisions including park layout, types of rides, number of rides, concessions, scenery, etc. The park guests play a vital role in the design by providing a statistic called the park rating (PR). The PR is a number between 0 and 1000 that reflects the guests' overall impressions of the park. A high PR is a result of good management decisions by responding to the needs of the park guests.

Substantial time was needed for the students to become familiar with the game functions. INEG 1103 lab meets for 75 minutes once per week, so it was decided that a two week lab would be required to complete one activity. The first week was basically devoted to learning how to play the game, with the exercise being completed the second week. Once the initial week was invested to learn the game functions, other activities using the same game could follow.

The first lab activity was to have the students identify entities that affect the PR through a combination of game-play and experimentation. Then, through the use of a cause-and-effect diagram and experimentation, the students were to determine some of the most important aspects of achieving a high PR.

The INEG 1103 students were asked to produce a lab report using power point including:

a. A ***Cause-and-Effect Diagram*** with **Low Park Rating** as the problem statement.
b. A collection of data recorded from the experiments.
c. The three most important causes in Roller Coaster Tycoon 2 that lead to a high park rating.
d. A discussion of ways to address these causes in the game to maximize park rating.

The 8th graders are asked to produce an activity report including:

a. Daily log entries to discuss progress.
b. A list of things that influence the park rating.
c. A table of data recorded from their experiments.
d. Park rating data displayed in an appropriate graph.
e. A ***Cause-and-Effect Diagram*** with **Low Park Rating** as the problem statement.
f. Completion of related questions and a written discussion of the activity.

The second lab activity was to have the students determine if a queue line in the game can be modeled as an M/M/1 queue. They were to open a new ride in the park and take measurements of the service rate (μ) of the ride and the arrival rate (λ) of the guests. From these two parameters they then calculated four quantities: Expected number of guests in the queueing system, expected time in the queueing system, expected number of guests in the queue, and expected waiting time in the queue. These calculated values were then compared to observed numbers in the game to determine if the M/M/1 queue model provides a reasonable approximation of the actual queue.

The INEG 1103 students were asked to produce a lab report including:

a. A description of the measurement process used to get (μ) and (λ).
b. All calculations performed.
c. A discussion of the reasonableness of the calculated numbers.
d. A discussion of the assumptions of an M/M/1 queue.
e. A list of difficulties encountered in this activity.
f. An investigation of other queueing models.
g. An explanation of why simulation is often used to evaluate queueing systems.

An activity for junior high students was not developed in this area because of the necessity of an understanding of basic queueing theory.

The computer simulation game, *Zoo Tycoon: The Complete Collection,* was chosen as the context for developing an engineering and problem solving exercise for an introductory Industrial Engineering Lab, INEG 1103: Principals of Industrial Engineering. For the *Zoo Tycoon* simulation, the focus was on customer driven quality control. "Customer-driven quality demands constant awareness of changing customer wants and needs and rapid response to meet these requirements."[3] The objectives for the lab included completing a Pareto Analysis, which orders occurrence data by category and helps pinpoint the right problem to study, on guest satisfaction and scatter plots comparing admission price to percentage of guest attendance at two marine shows to determine optimum returns. Qualitative data analysis was also conducted through guest opinion surveys.

Sixth grade students completed similar studies during a two week investigation. As the students progressed through the unit of study, they began to develop some basic understanding of the fundamental ideas relating to engineering problem solving and logistics. They were also able to understand some of the mathematical tools and models used by engineers as they worked through specific problems in the simulation. The students collected and analyzed data

throughout the scenario regarding zoo ratings, guest satisfaction ratings and exhibit ratings. Data collected included customer satisfaction, attendance at a marine show which kept a constant admission price, admission to a marine show which had an inflating admission price, zoo rating, and zoo income.

The activities in this unit were designed to meet the specific needs of middle school learners. They were interactive and of high interest to the typical middle level student. The park scenario enabled students to conduct problem-solving exercises in a real-world setting. "Games resemble experiences in real life. The main advantage is that time between certain events can be controlled and adapted, accelerating the learning process. Simulation Games are not limited to teaching cognitive learning goals. Moreover, skills like decision making, communication, and networking are implicitly promoted."[4]

Communication skills, both written and oral were stressed throughout the unit. Students kept journals and completed data tables throughout the unit of study which helped them stay focused on the targeted objectives. At the conclusion of the study, groups of students made presentations to the rest of the class on their projects.

Observations/Conclusions

The sixth grade unit was completed on October 22, 2004. About 150 sixth grade students were exposed to the material presented through the lessons taught using the *Zoo Tycoon* software. Several parents came to school the second day of the unit with concerns regarding the curriculum and also on how their students would be graded considering that we were using a "video game". They were shown the state frameworks as well as the National standards from math and science that were being addressed through the use of the software. They also saw the type of data collection that their students were completing. By the end of the unit, the same parents contacted me again, stating that they had to purchase this game for their children so that they could continue with what we were doing. Comments were also made like, "I wish we did things like this when I was in school." One mother made a point of coming to school and telling me that her son had always hated school and was extremely difficult to get up in the mornings. She said that whatever I was doing was great, because it was the first time he was motivated and wanted to come to school on his own.

The sixth grade class contained a heterogeneous grouping of students, ranging in ability level from those receiving special education services to those in the gifted program. By working with partners, all of the students were not only successful in completing the unit requirements; they also learned the value of cooperation. Decisions that they made together affected the outcome of the game, so after a few initial quick decisions, the students learned to take the time to think critically and also to project what might happen if they made certain choices.

The sixth grade students had not worked much with data collection. This experience allowed them to collect a variety of different types of data, determine which types of graphs would best illustrate the data collected, and also make forecasts and recommendations based on the data collected. The students were able to make real-world connections to the materials being studied.

No one complained with the standard, "Why do we have to do this?" Also, the absentee rate for sixth grade was at its lowest while we were engaged in this study. No one wanted to miss their lab days!

At the conclusion of the unit, the students were required to write papers explaining why their ratings were high or low. They also made recommendations for bringing their ratings higher. Because of the high interest of the students and the number of requests to do more, arrangements were made to take the students back to the computer lab at the end of the year so that they could implement the changes they recommended earlier in the year.

In conclusion, this material was found to be extremely beneficial to the students. They learned several important concepts and developed much needed problem solving skills. Motivation was also extremely high. This experience was also used to illustrate to the students possible career choices, including engineering, and how decisions they would be making in high school would affect their success in college. Many students expressed new interest in taking additional math courses and science courses such as physics, largely due to the interest built up by playing the selected game.

For the eighth grade students, implementation of the cause-and effect diagram activity into a junior high classroom was a success with some interesting effects. The activity was performed in a mathematics reinforcement class called "reasoning workshop" at Gravette Junior High. The students were excited to play RCT2 as an activity, and began working in groups of three. It would have been better if each student had his/her own game, but limited computer space made that impossible.

The forty-five minute classes passed much too quickly from the students' point of view. They saved their games daily and started there the next day. The students worked through the activity with a few problems, most of which were related to manipulating the game controls. Only one of the twenty-two students had extensive knowledge of this particular game prior to this activity.

Creating the cause-and-effect diagram provided a time to reflect and discuss the exercise with peers and a time for a discussion with the class about career opportunities in engineering and computer programming. It is a treasured opportunity when eighth graders are receptive to a conversation about the future and that was a very positive result of this activity. While the activity was in progress, the students involved also became more focused on their regular math class, which was a welcome surprise.

Overall, both projects were well received by the students and provided worthwhile instruction.

References

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Biographical Information

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Melissa Miller is a sixth grade teacher at Lynch Middle School in Farmington, AR. She has taught for 20 years, with most of her experience at the 5th and 6th grade level in math and science. She is a 2003 Milken National Educator and a 2001 Presidential Award winner, and is currently serving as President-elect of the Arkansas Science Teachers Association. This is her second year as an Industrial Engineering RET teacher.

RANDALL REYNOLDS

Randall Reynolds is an eighth grade teacher at Gravette Junior High School in Gravette, AR. He has taught Pre-Algebra for all 6 years of his teaching career. His Arkansas teaching certifications include math, physical science, and physics. This is his second year as an Industrial Engineering RET teacher.