2006-1216: ASSESSMENT OF SHORTFALL: A BOARD GAME ON ENVIRONMENTAL DECISIONMAKING

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Assessment of Shortfall: A Board Game on Environmental Decisionmaking

Abstract

Significant disparities in the learning styles of millennial students (students born after 1980) and those of their instructors have been documented. *Shortfall* is a board game designed to raise awareness of the concept of environmental decisionmaking in the supply chain. The project explores the hypothesis that millennial engineering students approach learning in a communal, active manner using trial and error approaches. Results of this pilot exploratory project suggest that engineering students are able to learn new information in a collaborative game approach, which impacts their confidence and self-awareness of their knowledge base.

1. Introduction

The goal and challenge of the board game entitled *Shortfall* is for students to learn to maximize profit with an increased awareness of environmental impact. The objectives of the game are to foster better understanding of these issues and to encourage potential future industry leaders to make these practices part of every day planning. The auto industry represents excellent opportunities to investigate the relationships among design considerations, supply chain management, environmental issues, research and development, and profitability. The original idea for the game was developed through a MS thesis[1] as part of an integrated research/ education plan for NSF supported work. Classroom exploration of the tradeoffs in the triple bottom line (economic, environmental and social performance) is most often limited to traditional lectures and descriptions of case studies. Instead of using a lecture format for green manufacturing, we tested and evaluated the potential for successful learning outcomes through participative group game play, cooperation and communication. The supply chain is simplified, but allows students to experience the ramification of materials processing decisions, i.e., technological solutions on the triple bottom line through an educational format designed to appeal to the generation labeled as millennial.

The decision to use a game methodology reflected, in part, a response to the current educational concerns around the millennial generation of students and their impact on higher education[2]. The differences in learning styles of the millennial student are already having an impact on learning and teaching in higher education[3-5]. Given the technological context in which children are raised in the U.S., the standard lecture and textbook homework assignments may not be the best method for teaching and communicating new ideas. It is our belief that this game will encourage the exploration and adoption of new, more exploratory teaching techniques. The prospect that a learning tool of this nature will encourage entrepreneurial and interdisciplinary thinking presents significant opportunities for transformation of higher education. The strategy to use well-designed, challenging games for educational purposes may lead to new methods for teaching engineering design. These types of tools can stimulate students with alternative learning styles, and thus creating a more diverse work force.

In this pilot study, we explored the following research questions: Can millennial students learn by playing multiple iterations of a board game designed to meet their learning styles? Does playing the game actually teach them anything new? Students who played a very early board-

game prototype in the classroom remarked that they found the game to be stimulating, and made suggestions for improvement.

2. Defining the Pedagogical Issues

Redefining the Concept of "Teaching/Learning"

A major factor directly influencing the millennial student arrival in higher education is the basic assumption about what constitutes teaching and learning[6]. Instruction delivery is no longer bounded by physical location nor restricted to transmission of knowledge with the instructor as the source of knowledge. This project capitalized on that concept by allowing students to "play" and "learn" together without an instructor. Through this project we are beginning the process of assessing the hypothesis that learning can occur across physical boundaries and that independent peer-to-peer team interactions will produce knowledge and confidence gains.

Learning through Simulation and Gaming

The Society for the Advancement of Games and Simulations in Education and Training (SAGSET) is a voluntary professional society that formed in 1970 to improve the effectiveness and quality of learning through the use of interactive learning, role-play, simulation and gaming[6]. According to SAGSET, simulation and gaming are good teaching tools, because the participants are required to be "directly involved" in the decision making process and thus, allow for learning of interactive decision making. Such games and simulations create memorable experiences that motivate students to continue to learn.

Simulation games are designed to mimic the reality of the external world, but with simplified details relationships and time of play exaggerating real world experiences to improve understanding. This experience allows players to construct their own knowledge about a topic, and through role playing understand and possibly shift their perspective, which has the potential to impact their understanding of the relatedness of their future roles in management, manufacturing and design.

Games also provide a space in which players can test out behaviors such as aggression or collaboration, negotiation or non disclosure[8]. In the context of a game, players get immediate feedback in response to their actions, and in the process, they can try out strategies such as team building, collaboration, openness or non disclosure. Games allow us to develop and test strategies, test alternatives and their impact upon our goals in a much tighter, responsive time frame than the real world.

Learning Styles & Decision Making

An additional factor supporting the assumption of simulation and gaming as a learning tool is the research finding documenting the learning style of millennial students. Timothy Golden[9] from Rensselaer Polytechnic Institute has pointed out two significant differences in this population. First, they approach problem solving differently from their teachers. Previous generations (current faculty) utilized a logic-based methodological framework, while millennial students

favor a trial-and-error approach whereby each time they fail, they are taking a step towards learning how to succeed. The second factor points to the heart of teaching. Previous generations were taught critical thinking skills and came to the university seeking information and facts, often through lectures. Today's generation has unlimited access to information which they view as constantly in flux, therefore these students are more interested in action learning and results. *Shortfall's* underlying pedagogical framework is based on this upcoming generation's trial-and-error action learning approach, eschewing formal instruction. In addition, engineering students in particular have been shown to have a preference for active, visual, hands-on learning[10-13].

While previous generations have valued solitary contributions, today's students are communal in their learning style. Ron Zemke[14] has characterized these students as "leave no one behind attitude". This is a generation brought up with cooperative and collaborative learning models from kindergarten.

Environmental and Economic Tradeoffs Within Supply Chains

In determining a model industry in which to explore the research questions, the U.S. automotive industry seemed the most likely choice. Car manufacturing relies on hundreds of suppliers for components and materials to manufacture vehicles, with emissions released to air, water, and soil throughout the supply chain. With the concept of extended producer responsibility taking hold in the European Union, original equipment manufacturers (OEMs) are becoming concerned about environmental repercussions of material and manufacturing choices that affect the use and disposal phases of their products. With concerns for their own accountability, OEMs are beginning to require that their suppliers meet specific standards regarding their manufacturing and material choices. These requirements, on top of the ubiquitous demand for minimum cost, place new burdens on the various tiers in the supply chain. The communication between the OEM and its suppliers to achieve these goals can be collaborative, but in many instances, there is a level of competitiveness that prevents full disclosure of information between parties.

This conflict between business and engineering design choices and the complexity of the supply chain infrastructure can be difficult for new engineers to grasp. For those in business, it is equally difficult to understand how design tradeoffs are not so straightforward. Engineering students need be made aware of environmentally benign design and manufacturing methods, and the associated tradeoffs in cost.

3. The Game Mechanics – A Short Synopsis

In the pilot board game, players each take on one of four roles in a company: the CEO, the Environmental Manager, the Research & Development Manager, or the Production Manager. Groups of four players, one taking on each role, form teams, each of which takes responsibility for a company. Each company is given a position in a car manufacturing supply chain: the OEM who produces the cars, the first-tier supplier who produces the parts, and the second-tier supplier who produces the raw materials for the parts.

The game is played in a series of rounds, each of which represent a fiscal quarter. In the final round, teams "sell off" their companies, and the team with the most money wins. In our test

play, we played five rounds, including the "sell off" round. The first round took 30 minutes, while subsequent rounds took 5-20 minutes.

At the beginning of each round, a die roll determines the fluctuation in market demand for cars. The three managers on each team then meet with their respective CEOs to persuade them to allocate financial resources to their departments. During the negotiations, teams are allowed to communicate with each other in order to get a better picture of the current supply chain, or to separate themselves in order to discuss team strategy privately.

Once budgets are completed using provided worksheets, teams come together to negotiate sales. The car manufacturer sells to the public, as determined by a die roll from the beginning of the round; the first-tier manufacturer then sells new parts to the car manufacturer, and the second-tier manufacturer sells new materials to the first-tier manufacturer. The trick is that companies may only sell product that is ready to ship. This means that teams must plan at least one round in advance, hoping that their predictions about market fluctuations will be correct.

After the sales phase, the companies simultaneously produce new product. The production of new product is limited by: each company's production budget, the number of parts/materials that each company currently has available, and the amount of product and waste storage that the company currently has available.

Next, each Environmental Manager makes decisions on whether to dispose of waste cheaply or to recycle waste, which may have longer-term benefits. Finally, the R&D Managers spend any part of their budgets on factory improvements through the use of "Innovation Cards". Some improvements reduce waste, while others lower direct costs; other improvements may actually increase costs in the short-term but ultimately prove to be a required step towards better innovation.

At the end of each round, any unsold supplies, product or waste is assessed a storage charge, and then a "Current Event" card is drawn. These cards describe real-world situations ranging from worker strikes to landfill seepage. Sometimes there is an immediate penalty or reward to one or all teams; sometimes the card affects the play of the entire next round.

In the final round of the game (a number of rounds is determined before the game begins, so that players may plan ahead for the ending), players do not produce further products, but instead sell off remaining product and overstock supplies, and dispose of remaining waste. After everything is sold off and disposed of, the team with the most money wins the game.

4. Research Design and Assessment of Game Play

In the fall of 2005, engineering sophomores from MIM U310 Introduction to Industrial Engineering were solicited to play the *Shortfall* game. Twelve students self selected to participate. Final participants included nine females and three males with self reported GPAs ranging from 2.87 to 3.92.

Prior to playing the game, students were administered a pre/test knowledge survey[14]. This type of survey was selected for its dual purpose: 1) it serves as a pre/post direct assessment measure of student knowledge and 2) it measures changes in pre/post self-assessment of student confidence in their knowledge base. Students were asked to answer 10 questions (Table 1) regarding their knowledge of supply chain and environmental issues related to manufacturing. They were also asked to rate their confidence in answering the question: **A** if they felt confident that they could now answer the question sufficiently if this were a graded test (which was scored numerically as 3); **B** if they could now answer 50% of the question or if they know precisely where to get the information needed and return in 20 minutes or less to provide a complete answer if this were a graded test (which was scored numerically as 2); and **C** they were not confident that they could adequately answer the question for graded purposes at this time (which was scored numerically as 1).

After playing the 5 rounds of the game for approximately 80 minutes, students were administered the same knowledge survey. Additionally, after round two of the game, students were administered a brief survey asking what *new* information they had gained regarding supply chain and working in a team situation.

Students were asked at the end of the game to respond to a program survey identifying the strengths and weaknesses of *Shortfall* as a board game. Lastly, one week after the playing the game, students were invited to return for a focus group exploring their experiences with the game and their perceived feelings about *Shortfall* as a learning tool. Nine of the twelve original students participated in the focus group.

Knowledge Survey

Table 1: Questions for Knowledge Survey

Q1	What are 3 positive features of just-in-time manufacturing?
Q2	List 5 environmental issues associated with production systems in an automotive supply chain.
Q3	Name 3 processes associated w/ the reclamation of waste material from manufacturing processes.
Q4	Identify 2 government based standards that impact the manufacturing of an automobile.
Q5	Identify 2 operations in the manufacturing life cycle that can be performed by automated equipment.
Q6	In what areas do companies make trade-offs when striving to maximize profits?
Q7	What types of materials are used in the production of engines?
Q8	Identify 5 main characteristics of a successful supply chain.
Q9	Name 5 events external to the main supply chain that can impact business practices.
Q10	Name 2 materials that are necessary to produce an automobile but may not appear in the final product.

Analysis of the questions in the knowledge survey (Table 1) showed that on average, students gained new knowledge and a changed perception of their confidence in their answers as a result of playing the game. As indicated in Figure 1, the mean scores reflecting the change in knowledge resulting from playing *Shortfall,* preliminary results seem to indicate a gain in knowledge on all questions with the exception of question 7. Increases in knowledge varied from a mean value of +0.08 (σ =0.79) in question 10 to a mean value of +2.42 (σ =1.16) in question 9. Question 7 resulted in an overall decrease in knowledge (x = -0.42, σ =0.51)

Analysis of the confidence data showed that in general, students felt more confident about their knowledge (see Figure 2) after playing *Shortfall*. However, there was decreased confidence in their ability to answer questions 5 and 7.

Qualitative analysis of the student perceived learning after round two revealed a new understanding of the role of waste in manufacturing, cost factors in R&D and storage, the connections between supply chain tiers, and the role of unexpected factors in manufacturing. One student put it best, "I did not know anything about supply chain and now I know about basic features about what happens after each step."

Students also came to a new appreciation of business structures and team work. The strongest perceived learning was in two areas: importance of communication and the role of working together. As a student stated, "everyone has to know what is going on or else you can't play as a team and make decisions", another student couched their response in terms of trust – "(you have to) give your input, but trust the person in charge of the area, they have studied their area more than you have and everyone has to do their job".

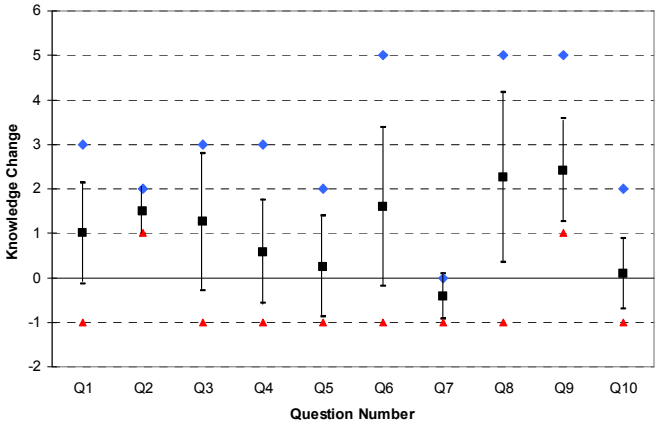

Figure 1: Mean knowledge change for each question in the knowledge survey, shown as black markers. Blue markers indicate maximum individual gain in each question, while red markers indicate minimums. Standard deviations are indicated for each question. (N = 12)

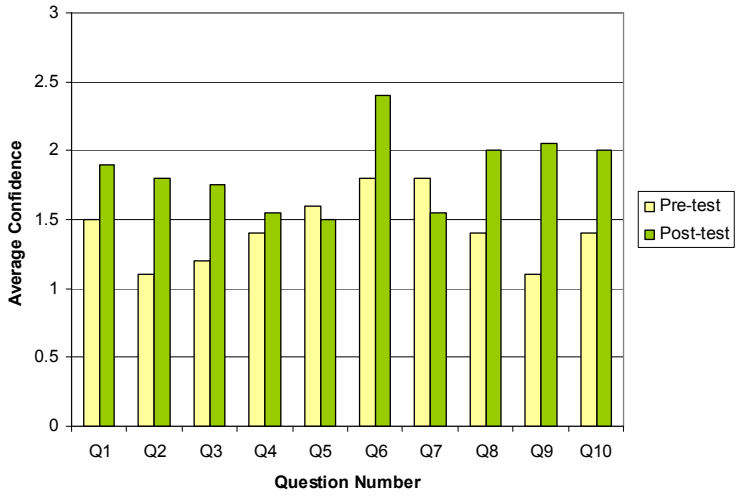

Figure 2: Average confidence of student knowledge before and after *Shortfall* game play

Program Survey

Feedback around perceptions of the game immediately following play produced useful and interesting information regarding the strengths and weaknesses of the game. There was a unanimous recording of students' enjoyment in playing the board game. Their feedback around improvements focused mostly on position of the board so that teams would not be within sight of each other.

Individual learning style differences were expressed in areas of introductory instructions. For most, the instructions were helpful and clear, however others described needing to play a round in order to make sense out of the game. The largest area of suggested change revolved around the 5th round. The students did not understand the purpose of the round and that created problems that were not anticipated by teams. There were also suggestions of more graphic directions (visual learners) or a comprehensive rule book for each team.

The Current Event cards were uniformly agreed to be clear and concise with little change needed. One student commented positively on the idea that it "threw some randomness" into the game. The only suggestion for change was more variety in the cards. The feedback on the Innovation Cards was less uniform. While many students found them clear, there was some feeling that these cards needed to provide more choices, that they should be worded differently, that some did not make sense in the context of playing, or that some were unnecessary and not really beneficial to the game.

The budget worksheets to record expenditures and profit seemed to be another positive aspect of the game. Student's opinions varied from "helps a little" to "helps a lot". But 1/3 of the participants felt that doing the worksheets helped them to better understand the overall concept of supply chain and the environment.

Feedback on the team roles showed that students felt that the roles need more definition and clarity. Students felt overlap existed between the roles and some felt their role as environmental or R&D manager left them with little to do. The CEO role seems to dominate and be the most active.

Their overall suggestions for improvement fell into two distinct categories. A majority of suggestions centered around the clarity of the game, i.e., better instructions, an initial overview, more introductory explanations, and clearer step by step directions. Other suggestions were looking for strategy planning and information on how choices affect the game. In the second category, suggestions requested making the game more realistic. Suggestions included allowing unlimited selling of cars, being told up front the technology on the market, and having an overview of each companies playing board.

Focus Group

The strongest theme resulting from the focus group was student perceptions that the game helped them more with the teamwork/communication aspects of supply chain than engineering or technical concepts. As one student said "it was strong on teaching people skills". This led

students to suggest that an improvement would be to make the game more realistic and more complex. Another suggestion was to make each team a manufacturing company that needs to work with the same supply chain, instead of individual parts of the chain. As one student stated, "in real life they work together in supply chains because they all want to make money." They also pointed out that in the final round everyone could sell off their company inventory and that the manufacturer could not lose but "in real life it would be hard to sell".

Another strong theme was the perception of *Shortfall* as a learning method. Almost unanimously students felt that it would function as a "lab", that is that most students felt they needed an introductory lecture first explaining supply chain, and then playing the game would solidify the concepts. While this was a fairly strong perception, there was also the feedback that the instructions were not clear and the game lacked a rule and reference manual. This lack of ability to find needed information quickly during the course of the game may have accounted for the students feeling that a content framework would be needed first to successfully play the game. A well-organized manual with superior index capability would allow "just-in-time" information retrieval on demand for students.

When asked to think about the process they went through to make strategic decisions during the game, students again identified that the initial rounds were devoted to "learning the game" and only after they understood how to play could they begin to play strategically. It also appears that the strategic aspect depended on how the CEO in each team functioned: some appeared to be more democratic and some more authoritarian. As students discussed roles, it became clear that the CEO role was confusing and that the R&D and Environmental Manager roles were not developed enough to be worthwhile. Some students in these roles said they "became bored" and thus learned less because they had less to do.

5. Summary

While the *Shortfall* board game has limitations, it did prove to be an effective and engaging learning tool around the concepts of supply chain and teamwork. Students documented learning more about supply chain and environmental factors after playing the game for a relatively short period of time and pre/post knowledge survey confirmed their perceptions. Students also gained confidence in the correctness of their answers after playing the game and with two questions identified their overconfidence in their initial beliefs. In other words, they were becoming more "consciously incompetent"[16] and understanding what they do not know. Students felt that engaging in a simulated supply chain allowed them to better understand the role of teamwork and communication skills in business environments. Clearly, they perceived *Shortfall* to be fun and engaging, and while they struggled with understanding the game during the initial rounds, they demonstrate having learned new knowledge independent of an instructor in a relatively short time frame. Due to the self selective nature of the pilot study, the number of women students may have introduced bias in the results, since ¾ of the participants were women, and provides limited generalizability of the results.

Correcting some of the shortcomings of the game may increase its value as a stand alone learning tool. Better constructed and delivered directions for the game as well as the development of a manual with pertinent information may eliminate the student's feelings that they need an

introductory lecture before playing the game. It is also possible that repeated playing of the game needs to be tested to determine if repetition will construct the needed knowledge framework to play the game. Reconceptualizing the game as teams of car manufacturing companies playing against each other may provide the more realistic aspects of the game that students identified as needing to increase motivation to learn. Our next step is to take this game to the next level of appeal to the millennial generation, which involves development of *Shortfall* as a computer game.

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