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Demonstrating The Elusive Outcomes of Decision-making, Information-seeking, and Adaptability: A Market Simulation Game for Engineering Students

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ABSTRACT

In undergraduate engineering education, students are often overexposed to problem-solving methods that are unrepresentative of how engineers solve problems in practice. For decision-making problems, in particular, students are commonly taught to compare alternative solutions using known and provided information. However, many real-world decision-making problems require a broader range of problem-solving strategies, including information seeking, extrapolation of a decision's consequences, and compromise between parties with competing objectives. To advance engineering educators' capacity to address this need, we developed a simulation game activity designed to offer industrial engineering seniors experience in solving realistic decision-making problems. The simulation game involved students working in teams that role-played as different types of companies in a global smartphone market, where teams needed to negotiate with one another to establish profitable contracts within the game's ruleset.

Using a qualitative assessment instrument we developed through prior research, we evaluated how well success in the game aligned with learning outcome achievement in constrained decision-making, information-seeking, and adaptability. Though the game has opportunities for improvement, student success in the game was aligned with excellence in constrained decision-making, and occasionally aligned with excellence in adaptability, and effort to seek information that could guide team decisions. Additionally, student actions during the game have potential to initiate student discourse on the role of engineering ethics in managerial decision-making, which may be of interest to many engineering programs. Finally, we comment on how our new assessment instrument affected student learning and related implications for assessment in engineering education more broadly. Our market simulation game was an effective instructional tool to allow students to demonstrate our intended learning outcomes, and other instructors with similar intended outcomes may find it a valuable tool for their courses as well.

Key words: Games, Problem solving, Outcomes-based assessment

INTRODUCTION AND PROBLEM DEFINITION

Research shows a disconnect between academia and industry in terms of engineering education and practice (Johri and Olds 2011). In particular, as we describe in a recent ASEE conference paper upon which this manuscript builds (Salado, Morelock, and Lakeh 2017), early career engineers believe that "engineering work is much more variable and complex than most engineering curricula convey" (Brunhaver et al. 2016). Success in engineering practice requires skills needed to solve ill-structured problems, such as problem formulation, communication, people management, decision-making, negotiation, and conflict resolution, among others (Hazelrigg 1998, Brunhaver et al. 2016, Lagesen and Sørensen 2009, Trevelyan 2010, Williams, Figueiredo, and Trevelyan 2014). For example, making decisions between alternatives, troubleshooting malfunctioning systems, and designing, all of which are examples of ill-structured problems, are common tasks of contemporary engineering work (Jonassen 2014). Yet, engineering education continues to focus on the use of equations and theories to solve well-structured problems (Jonassen 2014).

In our experience, exposing senior engineering students to problems that resemble the ambiguity and social characteristics of engineering practice (in the second author's decade of experience as an engineer in industry) reveals student difficulties in bounding, coping, and navigating through the ambiguity of problem definition. They display further difficulty in managing the complexity of dynamics associated with working with lack of information, operating in competitive environments, and incorporating uncertainty into engineering decisions. While engineers will acclimate to this context during their early careers as practitioners, engineering education can be adapted to help our students gain those skills as they learn traditional concepts, theories, and analytical methods.

Our Solution

To advance engineering educators' capacity to deal with these problems, we developed and implemented a team-based, role-playing simulation game that we employed in the Spring semesters of 2016, 2017, and 2018 in a senior level course on global industrial management, offered as part of the Industrial and Systems Engineering curriculum at Virginia Tech. Simulation games—procedural representations of reality consisting of systems in which players engage in artificial conflict, defined by rules, that results in quantifiable outcomes (Salen and Zimmerman 2004)—represent one means of creating problem-based learning activities, which foreground interaction with authentic, ill-structured problems (e.g., Dym et al. 2005, Jonassen 2014). Scholars Gee and Hayes (2012) argue that games can be understood as problem spaces, and the problems they contain can range from the well-structured spatial puzzles of *Tetris* to the chaotic & team-oriented disease proliferation in the board game *Pandemic* (Hadley 2014) and the ill-structured Rube Goldberg-type problems of *Contraption Maker* (Grohs et al. 2016)—a spiritual successor to the 90s hit *The Incredible Machine*. Moreover, these problems can be authentic if they are part of a simulation whose designers strive for high fidelity (Madhavan and Lindsay 2014, Shuman, Besterfield-Sacre, and McGourty 2005).

In our context, students learned industrial and systems engineering concepts and methods relevant to the game before playing it, by means of lectures, in-class interactive activities, and out-of-class assignments. The purpose of the simulation game was to reinforce, evaluate, and support the application of these concepts and methods to ill-structured problems. As we discuss in our prior conference paper introducing the game (Salado, Morelock, and Lakeh 2017), this purpose was translated to three main objectives, which tackled learning outcomes that are not easily addressed or captured by more traditional engineering education practices or more compartmentalized active learning activities.

First, the game was aimed at **fostering information-seeking tendencies,** where instead of relying solely on assumptions about a problem, students would seek appropriate questions and ask them to the game masters (instructors) and other game players (student teams) in order to reduce ambiguity and uncertainty. Second, the game was designed to **foster adaptability**, where the boundaries of the solution space depended on students' ability to act in accordance with conditions that changed in response to competitors' actions. Adaptability involved managing uncertainty through negotiations with other teams and innovating within the game's ruleset to secure advantages. Third, the game was built to **promote constrained decision-making**, as students needed to understand what information was needed to apply certain engineering techniques or make engineering decisions, as well as distinguish which decisions were appropriate for the given amount of information and time they had to complete the game.

The simulation game we developed (described in the Background section) was preceded by several similar games that were designed, implemented, and documented within the last 30 years.

Some notable examples include Cadotte's *Marketplace* simulation (Cadotte and Bruce 2003, Stahl and Dean 1999), Ammar and Wright's *Manufacturing Game* (Ammar and Wright 1999), and Dudziak and Hendrickson's contract negotiation game (Dudziak and Hendrickson 1988). The *Marketplace* simulation is intended for business student teams to integrate skills from several business disciplines by asking them to adapt to changing market conditions that react to their competitors' actions. *Marketplace* is still used in classrooms today through commercial software (Cadotte 2016), but we felt it was not ideal for our goals; while it foregrounds constrained decision-making and adaptation in an ill-structured system, it does little to promote information-seeking tendencies or student interaction—at least in the published forms of its complete ruleset. The *Manufacturing Game* requires engineers to develop a full suite of long-term planning documents for a production planning and inventory control system, and to then implement and adjust this plan in reaction to a blitz of financial results during a single class period. The *Manufacturing Game* is used in another course of our industrial and systems engineering curriculum, but we felt the need to develop a separate simulation game that better foregrounds adaptation to changing conditions and information-seeking tendencies. Finally, the contract negotiation game asks pairs of engineering student teams with competing objectives to come to an agreement on a single complex contract, requiring each to solicit information about the other team's goals and boundaries. While the contract negotiation game foregrounds information-seeking more than the other two games, we wanted to develop a game that incorporates negotiation in the context of a more ill-defined system over a longer period of time.

Our simulation game combines many of the features from the above games and also adds new features to fit our goal and context. Similar to *Marketplace*, we require students to adapt to competitor activity and market simulator results over several financial periods, but we encourage more interaction between teams and shed the focus on business skills. We encourage the types of negotiations foregrounded in the contract negotiation game, but require multiple simpler negotiations over several periods. Our game is quite dissimilar to the *Manufacturing Game* in structure and skill requirements, but requires similar attention to balancing product inventory and reacting to changes in product demand. Furthermore, we withheld information about some rules of our game to challenge teams to seek information about the feasibility of innovative strategies, which is a feature we did not see in any of the above simulation games.

The Purpose of This Work

This paper builds upon previous work advancing the assessment of our market simulation game, as reported in (Salado, Morelock, and Lakeh 2017). In our previous work, we used qualitative research methods to determine which learning frameworks were good fits to describe the experiences students reported with respect to each learning outcome. Metacognition emerged as an efficacious means of explaining the processes through which students made constrained decisions and sought information, and discrepancy resolution emerged as a way to describe why students did or did not adapt to changing game conditions. Using these two frameworks—which are defined in our Background section—we developed a more formal qualitative assessment instrument that was intended to assess the learning objectives more effectively and provide students with a metacognitive tool to guide student thinking throughout the project. Accordingly, the purpose of this work is to use the results from this assessment instrument to evaluate the market simulation game activity along the following research questions:

1. To what extent did behaviors congruent with the three learning outcomes align with student success in game outcomes?
2. What unintentional behaviors outside the scope of the three learning outcomes influenced student success in game outcomes?
3. How did the new, targeted assessment instrument influence student thinking or reporting with regard to the three learning outcomes?

Before continuing, we draw an important distinction between evaluating students on game outcomes (i.e., financial performance in the market simulation game) versus evidence of learning (e.g., demonstration of learning outcomes.) Particularly, our simulation game is designed to put student teams in competition with one another for in-game financial performance. Accordingly, evaluating students solely on in-game performance would provide an inaccurate measure of their learning outcome achievement, as there must be winners and losers (even if all teams demonstrate learning outcomes well.) This logic aligns with a plethora of educational literature on the philosophical and motivation-related issues with norm-referenced grading, in which students are evaluated in relation to their peers (e.g., Bong and Skaalvik 2003, Covington 1992, Mintzes and Leonard 2006).

However, while we believe that in-game performance should not be a determinant of student grades, the premise of this study is that our simulation game should be designed such that game outcomes align with learning outcome performance where possible. Game design scholars Salen and Zimmerman (2004) characterize the alignment of game outcomes with desired behavior as a central tenet of effective game design. As they articulate, "rewards and punishments are interpreted as positive or negative and gain force to shape player behavior" (Salen and Zimmerman 2004, 345). If players are not rewarded with positive game outcomes for exhibiting desired learning outcome behaviors, they will be less likely to continue pursuing those outcomes in the context of the game. We saw this situation manifest in our previous iteration of the game (Salado, Morelock, and Lakeh 2017), in which students who exhibited desired learning outcomes were discouraged when they performed poorly due to unrelated circumstances. Accordingly, a major goal of this study is to determine how well the current iteration of the game aligns game outcomes with learning outcome behaviors (RQ1), and how the impact of less desirable behaviors can be mitigated (RQ2).

BACKGROUND

The Course

Our market simulation game was employed as the final project in ISE 4304, a senior-level class on Global Issues in Industrial Management, offered at Virginia Tech in the Spring semesters of 2016, 2017, and 2018. This paper presents results from the Spring 2018 offering. The course had 71 students; 43 students majored in industrial and systems engineering, 21 in mechanical engineering, 5 in civil engineering, and 2 in packaging systems and design.

ISE 4304 is designed to make students aware of how international settings can influence the practice of engineering and provide them with the necessary mindset and techniques to become effective engineers in international contexts. In this regard, success in the course is considered as the ability to identify, discover, understand, and manage the economic, political, legal, and cultural differences in a given international setting to identify and resolve emergent ethical and global risks.

The course addresses the topics of globalization, the political economy of international trade, the foreign exchange market, the strategy of international business, differences in legal systems, differences in culture, ethics in international business, the organization of international business, global human resource management, and global production, outsourcing, and logistics. The course is structured into three main modules:

1. **Problem solving and modeling**. Students learn a generic process to solve ambiguous, unstructured problems by focusing on understanding what is being asked, structuring the solution without reaching to a specific toolbox, bounding the solution, and reasoning through its consistency, coherence, and validity.
2. **Contextual issues in international settings**. Students learn how to identify, frame, and resolve aspects related to ethical, legal, and cultural considerations in global settings.
3. **International engineering**. Students learn and apply engineering concepts related to international procurement and logistics (e.g., import and export tariffs and quotas), design approaches in international settings (e.g., organizational structures and adoption strategies), usability design for international markets (e.g., cultural preferences), and communication and culture in international teams (e.g., language barriers).

The three modules were administered sequentially. Instruction consisted of short lectures followed by in-class activities and out-of-class assignments. In addition, students had access to a list of key concepts shared through an online learning platform. The final project was administered after the first two modules were complete, midway through completion of the third module.

The Game

Our market simulation game was designed to provide students the opportunity to apply course concepts from all three course modules in a dynamic decision-making setting that reflected the kinks of ill-structured, socially involved problems they are likely to encounter in industry. Participation in the simulation was required as part of the course and was part of students' evaluation for the course. Students were randomly assigned to 15 teams with four to six members each. These teams were each assigned the role of one of three types of companies in a global smartphone market: Smartphone developers, technology companies, and smartphone manufacturers, all of which are described later in this section. There were five teams of each company type.

The game took place across six weeks, with each week acting as a simulated year in the global smartphone market. Each team needed to make certain decisions based on their company type (explained later in this section) at the end of each simulated year, and submit their decision documents by the end of the week. Necessary calculations for the market simulation were then conducted by the instructors over the weekend and each team received the results of the simulated year at the start of the week, in the form of their market performance and the results of their actions. Interested readers can find an example of weekly team results in Appendix A. All teams also received a weekly page from the Main Street Journal—a fictional journal for the game—that included a summary of market and regulation information. An example of this page can be seen in ***Figure 1***.

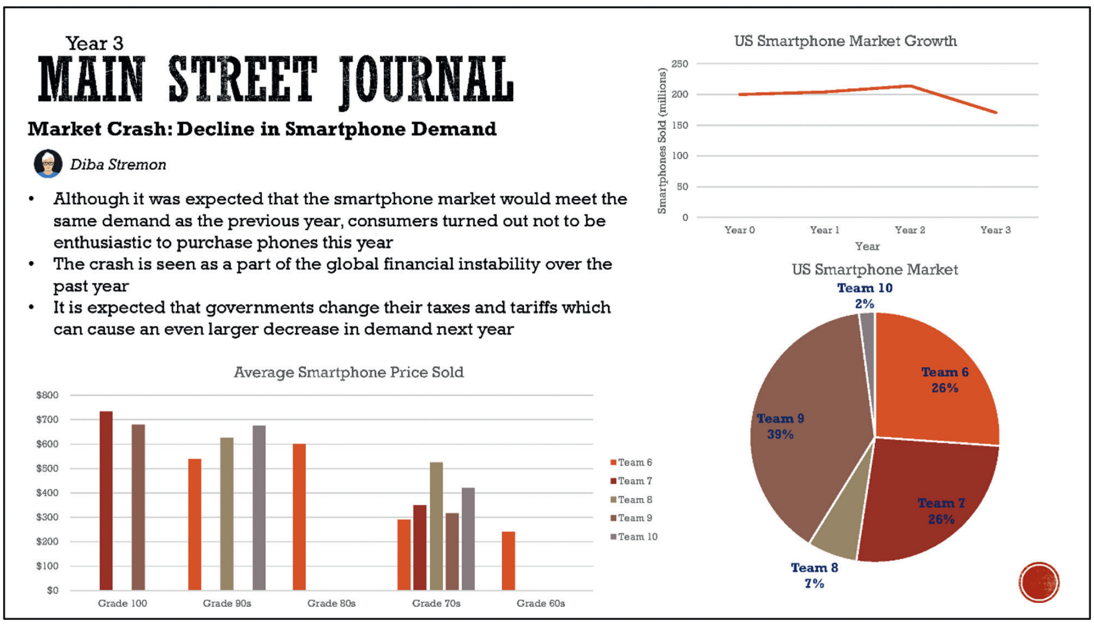

Figure 1. Example of a weekly page from the Main Street Journal, a fictional publication in the game.

All teams started the project with slightly different, randomized initial conditions. The project started with two "test" weeks, i.e., two low-stakes simulated years during which students could familiarize themselves with the game and the potential consequences of their actions. After these two years, all progress was reset and teams were once again assigned new sets of initial conditions. The project then ran for four simulated years, and these four years comprise the focus of our research. These four simulated years will be referred to as "real" simulated years, to contrast them with test weeks.

As mentioned above, there were three types of teams involved in this simulation. The developers were the firms responsible for delivering smartphones to end-customers, and the only company type to interface with the simulated consumer market. To acquire phones that could be sold on the market, they needed to collaborate with technology companies and manufacturers, who provided technology licenses and manufacturing capacity for smartphone development, respectively.

Technology Companies

Technology companies held patents for smartphone technology. These patents took the form of "technology grades," which represented the overall quality of the technology in phones produced. In this simulation, technology grade was modeled as a whole number between 0 and 100, where phones with higher grade technology generally sold for higher prices on the simulated consumer market. Technology grades were normalized each year such that the highest technology grade on the market was always Grade 100; lower technology grades were scaled accordingly. At the beginning of the first real simulated year, each technology company started with a patent for Grade 100 technology. If a technology company wanted to maintain its technology at its current grade in subsequent years, they had to pay a fixed maintenance fee each year. If they decided not to pay for the maintenance, their technology grade would depreciate at a constant rate (10%).

Technology companies could also invest their resources in research and development (R&D) to improve their technology grades. They all had two options for doing so: investment in incremental or breakthrough R&D. Investment in incremental R&D represented a low risk low reward strategy. In this approach, they had to invest a certain amount in R&D and as a result they could earn a technology improvement of between 4 to 7 grades, drawn randomly from a uniform distribution. Investment in breakthrough R&D was a high risk, high reward strategy. They could earn a much higher technology improvement of between 15 to 20 grades, also drawn randomly from a uniform distribution. In order to capture the high risk of breakthrough research programs and the exclusive benefits of the first-mover advantage (Lieberman and Montgomery 1988), breakthrough R&D was modeled as an auction in our simulation game. Each year, an auction would be held and technology companies that had invested money in breakthrough R&D and decided to enter the auction would lose all their investment in R&D and only the team with the highest investment would gain the breakthrough technology boost; other teams received nothing. Teams were not informed how much their competitors contributed. Breakthrough R&D made it possible for a team to earn a high technology upgrade with minimal investment if other teams chose not to opt in for this route (which did happen once in the Spring 2018 semester.) However, competition for earning the breakthrough technology boost can drive up the cost for this route of R&D. Therefore, technology companies had to come up with a clear strategy for R&D to maximize their rate of return on their investments.

Each technology company was located in a different country around the world and teams had their costs calculated in the local currency. Technology companies could earn revenue by licensing their technology grades to other teams, usually developers. They needed to negotiate with other teams and evaluate the market to offer their technology licenses at profitable but competitive prices.

Manufacturers

The manufacturers were responsible for manufacturing the phones. Three of the companies were located in China and the other two were located in Mexico. They made revenue by negotiating contracts with developers to manufacture a certain number of phones for an agreed-upon price. They all started the simulation with a randomly assigned set of operating costs for manufacturing phones and two manufacturing lines that could each produce a fixed number of phones each year. Manufacturers could decrease their costs in a few ways, including investing in improving the efficiency of their lines. They could also pay to expand their facilities, increasing the number of manufacturing lines available each year.

Manufacturers faced an uncertain and dynamic raw material cost, for which they had to make predictions in order to adjust their pricing. They were also able to recycle unsold smartphones. As stated previously, they could also invest in their companies in order to decrease their cost of operation or expand their manufacturing capacity. Advanced strategies such as self-investment for cost reduction and material recycling were not provided to the teams initially, but were released upon their inquiry, with the intention of encouraging information-seeking.

Developers

Finally, the developers had to decide how many phones they wanted to sell in a given year, what technology grades they wanted to use in their phones, and the selling price for each of their phones. They needed to get licenses from technology companies for the technology grades of their phones and pay the manufacturers to produce their phones for them. Developers represented the crux of negotiation during the game, constantly interfacing with manufacturers and technology companies. In addition to costs paid to technology companies and manufacturers, developers also faced fixed operational costs, regardless of the number of phones they sold, and fluctuations in market demand.

This game employed a market simulator that would determine the demand for smartphones each year. Based on this demand, it also calculated the quantity of phones sold by each smartphone company every year.

Learning Frameworks

Based on the results of our previous research (Salado, Morelock, and Lakeh 2017), we selected two learning frameworks as the structural foundation of our formal assessment approach for the market simulation game: Metacognition and Discrepancy Resolution. We present an overview of the two theories below, as we did in our preceding publication (Salado, Morelock, and Lakeh 2017), and we urge interested readers to read the preceding study for greater detail regarding how each learning framework was selected.

Metacognition

Metacognition is a learning framework that focuses on understanding and regulating one's own learning. While particular models of metacognition vary in their details, many contemporary models treat metacognition as a cycle that involves using one's metacognitive knowledge to select and regulate learning activities, which then allow one to update one's metacognitive knowledge (Ambrose et al. 2010, Cunningham et al. 2015). Metacognitive knowledge refers to three kinds of knowledge: (1) knowledge of self, particularly one's own strengths and weaknesses; (2) knowledge of tasks, including the requirements of a given task and what one needs to succeed in accomplishing a task; and (3) knowledge of strategies, encompassing different ways one could approach a problem (Cunningham et al. 2015, Flavell 1979, Pintrich 2002). These types of knowledge are then applied to regulation of one's cognition, including planning an appropriate approach to a task, executing one's strategy, monitoring progress, and adjusting one's approach when necessary (Ambrose et al. 2010, Cunningham et al. 2015). We previously found that metacognition was effective in explaining how student teams leveraged information and constraints to make decisions (Salado, Morelock, and Lakeh 2017).

Discrepancy resolution

Discrepancy resolution is a theory stating that learning occurs when there is a perceived discrepancy between an individual's expectations and perceptions of reality (Copple, Sigel, and Saunders 1984). It is part of the constructivist learning paradigm, which asserts that people learn by constantly revising their mental models of reality, integrating new information with prior knowledge of how the world works (Brooks and Brooks 1999). Thus, according to discrepancy resolution, if perceived reality does not conflict with one's existing mental model of reality, then the mental model needs no revision and thus no learning takes place. Importantly, discrepancies have to be perceived by the learner in order to be acted upon, as the learner cannot seek to resolve a discrepancy that he or she has not noticed (Copple, Sigel, and Saunders 1984). We previously found that discrepancy resolution was effective in explaining why some teams elected to adapt to suboptimal conditions, while others did not (Salado, Morelock, and Lakeh 2017).

RESEARCH METHODS

Data Collection

All data collection took place in the context of the sole Spring 2018 offering of ISE 4304, which included 71 students divided into 15 teams for the purposes of the market simulation game. We collected assignment data from each team in the form of a weekly report using the assessment instrument we developed from previous work (Salado, Morelock, and Lakeh 2017). The assessment instrument featured the questions in ***Table 1***, with the learning framework to which they mapped marked in [square brackets]:

Students submitted a report answering these questions every Friday for all six weeks of the project. Students were informed that "this week" referred to the week in which the report was submitted, and "last week" referred to the week prior. Finally, after the game ended, each team submitted a more general final report that addressed similar reflective questions across the

Table 1. Assessment instrument – Weekly report prompt provided to students.

Reflections on last week's results

1. [Discrepancy Resolution] Were you satisfied with your performance last week? Why or why not?
2. [Discrepancy Resolution] How did your actual profits from last week differ from your anticipated profits for that week?
3. [Metacognition – progress monitoring; knowledge of strategies] What strategies did you employ last week that may have accounted for differences between your expected and actual performance? What did your team do well? What could you have done better?
4. [Metacognition - knowledge of self; approach planning and adjustment] How did you adjust your strategy this week to accommodate your lessons from last week? Why do you think your new strategy is a good fit for your team's situation?

Reflections on this week's activity

5. [Metacognition] Describe your team's activity this week, including:
    a. [Knowledge of tasks] Your goals for the week (be specific)
    b. [Approach planning] Your initial plans for achieving those goals
    c. [Approach adjustment; progress monitoring] Any changes or adjustments to your initial plans for the week, including what prompted the changes
6. [Metacognition – knowledge of self, knowledge of strategies] What new information did you need in order to successfully implement your strategies this week? How did you acquire this information?
7. [Metacognition – progress monitoring] How well did you think you achieved your goals for the week?

Table 2. Data available for analysis.

	Teams															
	Manufacturers					Developers					Tech Companies					
Assignment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Total**
Week 1 Report	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	✓	✓	✓	✓	13
Week 2 Report	✓	X	✓	✓	✓	X	✓	✓	✓	✓	X	✓	✓	✓	✓	12
Week 3 Report	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Week 4 Report	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14
Week 5 Report	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	14
Week 6 Report	X	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	X	✓	11
Final Report	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15
Total	6	6	6	7	6	6	7	6	6	7	6	6	6	6	7	**94**

scope of the whole project. All teams were required to submit reports. Participation in our research (i.e., inclusion of the reports in our data analysis) was voluntary. This study was approved by Virginia Tech's Institutional Review Board, and students were asked to make the decision to consent or not consent as a team—requiring signatures from all team members—and all teams elected to consent. However, most teams lapsed in their report submission for at least one out of the seven reports. Accordingly, ***Table 2*** displays our final collection of 94 reports examined during data analysis.

Data Analysis

Following the methodological practices outlined by Miles, Huberman, and Saldaña (2014), we analyzed the 94 reports in two phases to answer our research questions. The first phase was participant-focused, using the method of analytic memoing to understand the week-to-week experiences of each team. Our analytic memoing process involved documenting moments, decisions, and actions that teams reported as pivotal in their weekly performance (operationalized as their financial performance at the end of each week.) These memos allowed us to achieve a big-picture perspective on the experience of each team, both familiarizing ourselves with the data and helping us identify unintentional behaviors that the game may have encouraged—which helped us answer our second research question. We were also able to compare these memos to the vignettes we constructed for each team in our previous implementation of the market simulation game (see Salado, Morelock, and Lakeh 2017) to determine how our new assessment instrument may have affected student thinking or reporting—which helped us answer our third research question.

Table 3. Variables analyzed for each learning outcome.

Learning Outcome	Variables Captured via Document-Level Coding
Constrained decision-making	• Decisions made • Constraints acknowledged
Information-seeking	• Information sought • Source(s) of information utilized
Adaptability	• Discrepancies noted between expectations and results • Adaptations made in response to discrepancies

The second phase of analysis was variable-focused. We conducted document-level coding that detailed how student activity described in each report aligned with our intended learning outcomes. ***Table 3*** documents the variables we captured for each learning outcome.

The goal of the second phase was to answer our first research question on how learning outcome behaviors aligned with game outcomes (i.e., in-game financial performance.) To do so, we created a rubric to evaluate project-level performance for each learning outcome; this rubric is included as ***Table 4***. We then used our document-level codes to grade each team on each learning outcome, based on the rubric. Finally, we compared each team's performance on the three learning outcomes to their overall financial performance at the end of the game. In looking at patterns across these variables, we were able to determine how performance in each learning outcome aligned with each team's final score (represented via their overall financial performance.) For example, one of our results was that manufacturers and developers with excellent performance in constrained decision-making tended to emerge with the highest final scores. Thus, we concluded that the in-game performance aligned with constrained decision-making for manufacturers and developers. Appendix B provides an example of an analytic memo for a developer team, augmented with our document-level coding and learning outcome assessment.

Table 4. Rubric used to evaluate each team's project-level performance in each outcome.

Learning Outcome	Excellent Rating	Satisfactory Rating	Unsatisfactory Rating
Decision-Making	Proactively anticipated constraints and actively made decisions that incorporated them. Focused on long-term success under the game's set of constraints.	Failed to anticipate key constraints but actively made decisions that incorporated them when discovered. Considered long-term implications of decisions.	Decisions not clearly connected to constraints. Decisions focused on short-term gain rather than long-term consideration.
Information-Seeking	Consistently and proactively sought information about the game or social context from instructors or other teams. Asked about the viability of creative new strategies.	Sought information from instructors or other teams reactively (e.g., in response to a perceived discrepancy or obstacle.)	Rarely sought information from instructors or other teams. Relied primarily upon information provided in weekly reports.
Adaptability	Consistently identified and addressed discrepancies each week. Readily adjusted strategy when setbacks occurred.	Occasionally identified and addressed discrepancies. Preference toward a particular strategy with willingness to flex when necessary.	Adaptations limited to minor tweaks. Reluctance to deviate from a strategy in the face of setbacks.

In this second phase of our analysis, we did not include the two test weeks that took place before the game's real simulated years, as these weeks were intended to level the playing field by familiarizing all students with gameplay. Additionally, in the last real simulated year, many teams decided to pursue end-game strategies and their decisions were affected by the knowledge that the simulation is about to finish. This disrupted the market and had adverse, unfair effects on teams with lower performance in prior weeks. Thus, we excluded the final week of the game from our analysis.

Before continuing, we should note that students' grades were not tied to their final scores in the game. The game established that teams needed to compete for shares of a limited market, which created a zero-sum scenario that made final scores a poor basis for grading. In addition, company performance was affected by uncertainty out of the teams' control, which would be unfair to factor into course grades. Rather, grades were assigned based on the quality of their reports in terms of describing their decision-making processes. In this way, for example, students were graded on how they incorporated uncertainty in their decision-making processes, not on the effect that uncertainty had on the materialization of the consequences of those decisions. This approach is consistent with the characteristics of good decisions laid down in decision theory (Howard and Abbas 2015).

Nonetheless, as we established earlier, our goal in creating this game was to establish a simulated environment in which excellence in our three learning outcomes is rewarded through high in-game performance in terms of profit. Accordingly, our research questions and results focus on how well the gameplay—in its current form—afforded achievement of our three learning outcomes, and how well excellence in these outcomes related to in-game performance.

Research Quality

We followed several recommendations outlined by Anfara, Brown, and Mangione (2002) to improve the dependability, credibility, and transferability of our qualitative research. First, to improve the dependability of our results (the qualitative counterpart of reliability), we conducted an intercoder reliability check to triangulate results between researchers. The first author conducted the primary analysis to assess each team based on the rubric in ***Table 4***, while the fourth author used the same analysis process to evaluate two purposefully selected teams from each company type (six teams total.) Results were then compared to reveal five patterns of bias in the first author's assessment of constrained decision-making and adaptability. The first author then re-evaluated all remaining teams with these patterns in mind, leading to several evaluations being corrected to align with the criteria established in the rubric.

Second, the credibility of our results (the qualitative counterpart of internal validity) was enhanced through peer debriefing, in which the results of the first author's analysis were reviewed and agreed upon by the second and third authors, who were responsible for running the game and familiar with

Table 5. Number of teams achieving each outcome to various degrees of excellence.

	Excellent	Satisfactory	Unsatisfactory	N/A[a]
Constrained Decision-Making	6	9	0	0
Information-Seeking	7	6	1	1
Adaptability	8	5	1	1

[a] Not enough information in the team's reports to evaluate learning outcome using rubric.

the game and its trajectory based on that experience. Finally, readers can use the detailed descriptions of the game and course context at the beginning of this article to determine if this kind of intervention and our results are transferable to their academic contexts.

RESULTS

Learning Outcomes Achievement

Table 5. Number of teams achieving each outcome to various degrees of excellence. outlines the number of student teams (out of 15 total) that performed at a high, moderate, or low level with respect to each learning outcome. Few teams scored unsatisfactorily on any outcome, and an Excellent rating was more common than a Satisfactory rating in all outcomes except Constrained Decision-Making. Most teams (10 of 15) demonstrated excellence in at least one learning outcome, and half of those (5 total) demonstrated excellence in all three outcomes.

These results led us to two conclusions. First, the assessment instrument we developed was effective in soliciting enough detail from student teams to map teams to the rubric on each learning outcome. There were only two cases where we did not have enough information to use our rubric, and in these cases, the students either did not answer the first half of our instrument's questions (i.e., they did not submit complete reports) or did not answer questions completely.

Second, given that almost every student team received Excellent or Satisfactory ratings on each learning outcome, we conclude that the game provided a good context for students to exhibit each outcome to varying degrees of excellence, and—based on our analytic memos—in a diversity of ways. One example of diversity in teams exhibiting outcomes is the difference in how manufacturing Teams 3 and 5 scored excellently in decision-making. Team 3 based its weekly decisions on a carefully calibrated cost prediction model it developed through a strong grasp of the game's technical constraints, such as costs and exchange rate fluctuation patterns. On the other hand, while Team 5 had a decent grasp of the game's technical constraints, the team earned its outcome rating through a deep understanding of the game's social constraints, using bulk deals and taking on the burden of currency conversion to facilitate deals with developers, and leveraging its competitors' spare capacity to propose mutually beneficial partnerships that reduced costs. We considered both these types of constraints important to consider, and thus we considered it crucial to give teams an avenue to demonstrate their decision-making abilities using either.

RQ1. Alignment of Learning Outcome Behaviors and Game Outcomes

The pursuit of profit was the ultimate objective students worked toward during the market simulation game, with monetary profit (in USD) acting as the game's point system to determine winners. Our logic in designing this game was that teams who exhibit excellence in learning outcomes should perform well in the market simulation game compared to peers who do not exhibit such excellence, thus demonstrating to students the importance of these outcomes in real-world engineering. Accordingly, we compared how a team's learning outcome performance (determined via the rubric in Table 4) correlated to its profit at the end of the game, in order to answer the research question: **To what extent did behaviors congruent with the three learning outcomes align with student success in game outcomes?** We found that the extent to which the game outcomes aligned with learning outcomes varied depending on the learning outcome and on the type of company each team roleplayed. ***Table 6*** exhibits each team's learning outcome performance and endgame profit.

Table 6. Performance of each team in terms of learning outcome performance & endgame profit.

Company Type	Team	Decision-Making	Information-Seeking	Adaptability	Endgame Profit (USD)
Manufacturers	1	Satisfactory	—	Unsatisfactory	$2,257,920,792
	2	Excellent	Excellent	Excellent	$4,904,954,370
	3	Excellent	Satisfactory	Satisfactory	$5,518,120,433
	4	Satisfactory	Satisfactory	Satisfactory	$(1,132,592,593)
	5	Excellent	Excellent	Excellent	$15,806,968,171
Developers	6	Satisfactory	Satisfactory	Excellent	$4,165,342,000
	7	Satisfactory	Excellent	Excellent	$468,116,000
	8	Satisfactory	Satisfactory	Satisfactory	$(317,668,000)
	9	Excellent	Excellent	Excellent	$4,836,354,200
	10	Satisfactory	Unsatisfactory	Satisfactory	$(12,602,096,825)
Tech Companies	11	Satisfactory	Satisfactory	Excellent	$5,508,682,741
	12	Satisfactory	Excellent	—	$(2,899,822,222)
	13	Excellent	Excellent	Excellent	$12,174,153,579
	14	Excellent	Excellent	Excellent	$(2,970,786,889)
	15	Satisfactory	Satisfactory	Satisfactory	$(2,805,242,994)

For both manufacturers and developers, in-game performance most closely aligned with excellent constrained decision-making as a learning outcome. For both company types, the teams that rated highly on constrained decision-making generated the highest profits. Furthermore, the two teams that scored unsatisfactorily in either information-seeking or adaptability had final profits below the majority of their peers within the same company type, suggesting that a minimum competency in these two outcomes was important to in-game success.

For developers that were rated as Satisfactory in their constrained decision-making skills—the vast majority—adaptability seemed to support better in-game than information-seeking. In all cases for these developers with satisfactory constrained decision-making ratings, teams with Excellent-rated adaptability emerged with more profit than peers with Satisfactory adaptability. Whether a team scored Excellent or Satisfactory on information-seeking did not seem to affect its endgame profit, though it should be noted that the one team with Unsatisfactory information-seeking (Team 10) ended with the lowest endgame profit. Overall, these results indicate that—for developers—game outcomes most closely aligned with excellent constrained decision-making and, to a lesser degree, excellent adaptability and at least satisfactory information-seeking. For manufacturers, on the other hand, only excellence in decision-making appeared to be predictive of in-game performance, suggesting that unintended outcome behaviors had a greater impact on in-game performance than the intended outcomes of information-seeking and adaptability. This phenomenon is further addressed in RQ2 results.

Technology companies were a different case entirely. In this instance of the market simulation game, learning outcome behaviors for technology companies related poorly to endgame profits. Two technology companies had Excellent scores across all three outcomes, but only one of them did well. In fact, only two technology companies had positive profits at all, while the other three had almost identical negative profits. In examining why, we determined that an unintended outcome behavior emerged among the leading technology companies (Teams 11 and 13) that detracted from the experience of other technology companies—identified by answering our second research question.

RQ2. How Unintended Behaviors Influenced Game Outcomes

Given that learning outcome behaviors did not always align with student success in game outcomes, we sought to answer a second research question: **What unintentional behaviors outside the scope of the three learning outcomes influenced student success in game outcomes?** We discovered that the game's design facilitated several unintended (and undesirable) behaviors that led teams to victory without demonstrating the intended learning outcomes, or that prevented teams who demonstrated excellence in intended learning outcomes from succeeding in the game. Technology companies were most acutely impacted by undesirable behaviors, particularly a merger and market monopolization strategy employed by Teams 11 and 13. Recognizing that developing and maintaining technology grades was expensive, these teams decided to merge via a profit-sharing contract in which they would share access to each other's phone technologies and split their profits evenly for the whole game (Team 13 did not reconfirm their contract in Year 3, though, which accounts for the discrepancy in their endgame profits.) This strategy effectively halved their maintenance cost for having access to two technologies compared to other teams, allowing them to not only offer their technologies to developers at a lower cost, but also to contribute substantially more capital toward the Ideas Auction.

We thought this strategy—spearheaded by Team 13—was creative, and it alone could have served as a catalyst for other teams to adapt and succeed. However, in addition to the merge, they decided to offer their reduced-cost technology to developers on a long-term contract basis, locking out other technology companies from over half the market at the very start of the game. Even though other technology companies were savvy in how they adapted and made decisions given the constraints imposed by the merge (Team 14 in particular), there were not enough developers willing to trade with other teams for other teams to succeed. It is clear to us that future iterations of the game should implement measures to prevent these kinds of long-term monopolistic tactics in order to better align in-game performance with learning outcome performance, and ensure that all teams have a fair chance of in-game success.

For manufacturers, the game's design may have ncouraged passivity instead of adaptability when facing challenges. Unlike the other two types of companies, manufacturers received no penalty for inactivity. Developers have to stay active to make up for the fact that their phones' technology grades deteriorate over time, and technology companies have to at least make enough money to cover their weekly maintenance costs. Manufacturing facilities, however, have the option of shutting down for the week (i.e., simulated year) without any gain or penalty (i.e., zero profit for that week.) When one manufacturer (Team 1) had trouble attracting developer partners, the team decided it would be more beneficial to keep pursuing the same strategy and hope for better luck, given that it did not lose anything for lacking a partner. Accordingly, Team 1 incurred no profits or losses in any game week except the last one, where they made a modest positive profit. In contrast, another manufacturer (Team 4) risked participating in an uncertain market and ended up with the less profit than Team 1 due to weekly losses, despite having higher outcome ratings according to our rubric. Future iterations of the game should implement a more realistic scenario, where there are at least amortization costs that manufacturers have to incur every year. Such a scenario would penalize idleness and provide a greater tension between the different alternatives for manufacturers, further encouraging adaptation in the face of hardship.

Finally, it should be noted that Team 5 was the most successful team in the game. While we believe the team earned its success through high performance in all three learning outcomes, we also noted that the innovation that had the greatest impact on the team's success was the employment of child labor in their factories. Because Team 5 located in a country with lax labor laws, it was able to use child labor to reduce labor costs without suffering any penalties. We suspect that readers are aware of how child labor infringes upon human rights, and that we do not need to justify why many would consider the use of child labor an unethical practice that should not be encouraged among students. However, as shown in prior work, such scenarios are realistic and engineering students may face them in the workforce, where they may be exposed to tensions between their own benefit and their own system of preferences and values (Salado 2017). Accordingly, students' ability (and choice) to employ ethically questionable strategies during the game provides an opportunity to initiate a conversation on how students identify, assess, and resolve (in teams with different systems of preferences and values) ethical dilemmas emerging from the tension between achieving victory through implementation of unethical strategies in pursuit of profit and the potential for negative consequences, such as economic sanctions or social penalties. Such discussions provide a forum for students to reflect upon how strategic decisions are weighed in professional situations and the roles of ethical codes and personal preferences and values in these decision-making processes.

RQ3. How Did The Assessment Influence Student Thinking or Reporting?

The goal of our new assessment tool was not only to evaluate student performance with respect to our learning outcomes, but also guide student reflection in line with the learning theories of metacognition and discrepancy resolution that we previously identified as efficacious theories to describe student learning within the game (Salado, Morelock, and Lakeh 2017). While we did not directly ask students how the assessment affected their reflective processes, we observed two differences in how students thought about or reported their decisions in this batch of reports compared to the unstructured reports from our previous study (Salado, Morelock, and Lakeh 2017), which simply asked students to explain their decisions each week. First and foremost, we noted that students placed a far greater emphasis on the game's constraints—imposed both by the game's ruleset and the social conditions of the competitive environment—when making week-to-week decisions. Students from our previous iteration reported adapting to perceived surprises or discrepancies as their primary motivations for action, while students in this iteration discussed discrepancies, other teams' anticipated actions, and various costs and rules to influence their regular decisions and actions. Second, students in this iteration more often reported on their information-seeking decisions. In contrast, only five teams from our previous iteration commented on their information-seeking processes.

DISCUSSION

In compiling our results, we noted several implications for the use of this market simulation game and its design in future iterations. Additionally, we deduced one important implication for the use of assessments in engineering education settings more broadly. We present all of these implications from a constructivist perspective on learning, which asserts that each student learns uniquely by building new knowledge atop a foundation of existing knowledge.

Implications For Practice: Using The Market Simulation Game

Despite several opportunities for improvement, we have noted throughout our results, we still found that the game was effective in providing students the opportunity to demonstrate our three learning outcomes in diverse ways. As we discussed in our introduction, the three learning outcomes we studied—constrained decision-making, information-seeking, and adaptability—are key skills needed to solve ill-structured problems in real engineering work, but are not easily addressed or captured by more traditional engineering education practices or more compartmentalized active learning activities. Accordingly, due to this benefit and the game's scalability to large classrooms, we encourage engineering instructors or programs interested in developing these outcomes to adapt the game to their contexts.

Moreover, from a constructivist perspective on learning, capturing the diversity of ways that learning outcomes can manifest is paramount, as even though two students may come to understand a concept in different ways, both may be able to apply their unique understandings to solve an open-ended problem in equally effective ways—even if the two solutions look quite different (Brooks and Brooks 1999, Newman, Griffin, and Cole 1989). Referencing our previous example, the fact that a student team can score as highly on the Constrained Decision-Making outcomes by leveraging social constraints as a team that leverages technical constraints indicates that the game and rubric reward diverse ways of knowing and problem-solving approaches.

However, despite the game providing an effective environment for students to demonstrate learning outcomes, we discovered that the game must be tweaked in at least three ways such that it does not favor teams that demonstrate undesirable behaviors. First, measures must be established to break up long-term monopolistic practices that bar other teams from the possibility of financial success, as occurred when two technology companies merged and established long-term, exclusive contracts with over half the developers. These measures could take several forms, but we believe the most effective solution would be to empower students to self-police the game. For example, teams could be made aware of the contracts their competition established in the previous week by means of the weekly market report, which would be akin to real-world publicity of partnerships between companies. With knowledge of these deals in hand, monopolistic interventions by the instructors could be student-driven, prompted by a formal complaint process added to the game's ruleset. We recommend a self-policing system for three reasons. First, it minimizes the need for instructor vigilance throughout the multi-week game. Second, forbidding long-term contracts altogether is not feasible, as students can self-organize informal long-term deals outside the instructors' purview. Third, it provides an opportunity for student teams to take initiative, which in turn provides an opportunity to demonstrate the learning outcomes.

The second necessary adjustment to the game involves implementing an ongoing cost for manufacturers that is independent of manufacturing activity, such as a basic overhead cost (rent, amortization, executive/full-time salaries, etc.) We expect this ongoing cost will discourage (and penalize) manufacturer idleness and therefore encourage risk-taking. Finally, the third necessary adjustment is to implement a potential for penalties for unethical behavior, such as the child labor employed by one of the manufacturers in our study. Again, we opt for a solution that gives students the information they need to self-police this undesirable behavior. For example, if a team reports using child labor, the instructors can send out a short "journalistic piece" with the next weekly market report announcing the discovery by local journalists that the company may be using child labor in its factories. Students could then self-police the unethical behavior by choosing not to do business with that team. Even if students choose not to self-police the behavior, they would at least have done so intentionally rather than by lack of knowledge, which can prompt a useful instructor-led discussion and reflection on the role of ethics in global engineering work.

Implications for Practice: Assessment in Engineering Education

Answering our third research question provided evidence that assessments not only evaluate learning, but also act as metacognitive tools to affect learning. This idea has been present in educational literature for decades (Black and Wiliam 1998, Earl, Katz, and Western and Northern Canadian Protocol for Collaboration in Education 2006), and is congruent with constructivist learning perspectives, which assert that learning is a goal-directed activity, and the questions asked on regular assessments can signal to students what goals are considered valuable by their instructors. However, the role of assessment in a learning context (rather than an evaluative one) has only recently become a topic of interest in engineering education literature, where conversations around the alignment of course-level and program-level assessments for the purposes of accreditation and data-driven program improvement have traditionally been more salient (e.g., Spurlin, Rajala, and Lavelle 2008, Olds, Moskal, and Miller 2005). However, we argue based on our findings that, when developing assessment plans, engineering educators could consider how the questions asked can metacognitively guide students toward the intended learning outcomes.

CONCLUSION

Our market simulation game provides an open-ended environment for student teams to demonstrate skills in constrained decision-making, information-seeking, and adaptability—three uncommon but nonetheless important learning objectives in engineering education. To assess the game's efficacy in rewarding behaviors related to these learning outcomes, we developed and employed a qualitative assessment instrument built upon the theoretical foundations of metacognition and constructivism. We determined that, while the game has room for improvement in preventing some undesirable student behaviors, student success in the game was nonetheless aligned with excellence in constrained decision-making, and occasionally aligned with excellence in adaptability, and effort to seek information that could guide team decisions. Additionally, we found that student actions during the game have potential to initiate discussions about the role of engineering ethics in managerial decision-making, which may be of interest to many engineering programs. We found our market simulation game to be an effective instructional tool that allows students to apply our intended learning outcomes, and other instructors with similar goals—and especially instructors in industrial engineering, engineering management, or systems engineering—may find it a valuable tool for their courses as well. We encourage any interested readers to contact our second author, Dr. Alejandro Salado, for any further questions regarding the game's design or implementation.

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APPENDIX A: EXAMPLE OF WEEKLY RESULTS REPORT PROVIDED TO STUDENTS (MANUFACTURER)

1. Revenue Information

Number of phones sold	Revenue in US Dollars	Revenue in Yuan
63,000,000	$ 14,364,000,000	116,061,120,000
44,000,000	$ 8,360,000,000	67,548,800,000
21,000,000	$ 4,725,000,000	38,178,000,000
22,000,000	$ 5,236,000,000	42,306,880,000
Total		264,094,800,000

2. Cost Information

Item	Cost (Yuan)
Subcontract to Team 1	72,720,000,000
Raw Material	133,870,000,000
Operation and Maintenance	3,850,000,000
Shipment	Paid by the smartphone development company.
Income Tax (20%)	10,730,960,000

3. Profit

Your profit at the end of third year is 42,923,840,000 Yuan. You have also spent 1,000,000,000 Yuan on lobbying which reduces your total profit to 41,923,840,000 Yuan.

4. Comments

You have five lines for the rest of the project.

The cost for setting up a new line for your team is 6,652,800,000 Yuan.

Your lobbying effort was not successful.

APPENDIX B: EXAMPLE OF A TEAM'S COMPLETED PROFILE (TEAM 9 - DEVELOPER)

Includes analytic memo, document-level codes, and learning outcome assessment

Test Run #1

No report submitted.

Test Run #2

1. Previous year summary:
    a. The team focused on introducing themselves to the manufacturers in the previous weeks and making "deals." However, they did not solidify any deals and thus had no phones manufactured and no revenue generated. They learned that they needed to close deals and understand the manufacturing process better in order to generate a revenue.
2. Current year actions:
    a. The group decided to solidify deals and dive more deeply in the numbers of the supply chain.
    b. They are also deciding to try to corner the market on a particular type of phone via self investment and more aggressive marketing.
    c. They are somewhat vague on the business model.
3. Document-level codes:
    a. Decision-making: Enter into long-term deals (to simplify later negotiating), upgrade phone tech, monopolize specific type of phone
        i. Constraints noted: Complexity of negotiating with multiple parties, uncaptured market ripe for monopolizing
    b. Information-seeking: Found out about ability to upgrade phone tech by talking to tech companies.
    c. Adaptability: Made sure to submit deals correctly to Arash
        i. Discrepancies noted: No deals submitted last week
4. Learning outcomes:
    a. **Constrained decision-making** – Acceptable; The team took into account their shortcomings from the first week and tried to double down on learning what is necessary to seek a profit. They also are being extra careful to make sure all deals are solidified.
    b. **Information seeking** – Acceptable; the team acknowledged their failings in the first week and actively sought out the information necessary to turn their business model around to become profitable.
    c. **Adaptability** – Excellent; the group did not underemphasize any of their shortcomings from the first week and took very strong steps to becoming profitable.

Year #1

1. Previous year summary:
   a. The team captured less of the market than others, but realized this was due to overestimating the influence of high grade phones and underestimating marketing.
2. Current year actions:
   a. This year the team reached out to more companies in order to better capture the market with competitive pricing. They are also choosing to invest a significant amount of capital into advertising and facilities in order to increase their production value. They did come across a very competitive deal and thus signed all of their manufacturing over to a single team.
   b. They did a lot of investigating into the functioning of the market. They learned that a significant portion of the market can be captured by advertisement but much is also dependent on their and other teams' performances.
   c. They actually broke down their marketing and reinvesting strategy based on units sold, which could play out to cause severe under investment or strong over investment.
3. Document-level codes:
   a. Decision-making: Shopping around for deals, settling for a single manufacturer, per-phone advertising and self-investment
      i. Constraints noted: Competition among potential partners, desirability of offers received, determination of market share and operating costs, no cash available
   b. Information-seeking: Gathered a lot of information from Arash about the market (specifically, market demand characteristics) and the effects of advertising and self-investment.
   c. Adaptability: Advertising and self-investment
      i. Discrepancies noted: Low market share in previous test week
4. Learning outcomes:
   a. **Constrained decision-making** – Excellent; the team is still incorporating experience and new knowledge into their model to a high degree. They are also closing on deals that maximize the benefit to themselves. They have also outlined long term marketing and investment plans after learning more about the market.
   b. **Information seeking** – Excellent; the team sought out information regarding the interactions between marketing and market capture. They also attempted to learn how corporate interactions impact the market.
   c. **Adaptability** – Excellent; the team observed the shortcomings in their plan based on their performance the previous week and changed their business model to improve their company and marketing investments. They also realized an opportunity to close a deal that was highly beneficial to their company and acted upon it.

Year #2

1. Previous Year Summary:
    a. The marketing and self investment paid off to generate almost 1/3 of the market capture. The team realized they did not project their profits but realize they should begin doing so.
    b. They placed their phones at a very low price point and thus ended up undercutting other developers and capturing much of the market for high grade phones
2. Current year actions:
    a. The technology company the team partnered with invested in their stock and maintained high grade phones. This allowed team 9 to remain in the high grade market but also gave them room to move into the sale of lower grade phones, diversifying their market share.
    b. The team is also changing their investment scheme to not be based upon sales, but upon profit generate (i.e. taking marketing funds out of liquid cash). They are decreasing the amount of reinvestment by 50%.
    c. The team is also structuring their deals so as to be enticing to manufacturers and tech companies.
    d. Found out they could recycle old phones to reduce manufacturing costs, so made trade-in deal for customers and recycling deal with manufacturers to reduce costs (also looked into patenting their trade-in deal to thwart competition.)
3. Document-level codes:
    a. Decision-making: Flat investment, expanding into low-grade phone market, trade-in deal, potential patent, continuing low prices, creation of profit model
        i. Constraints noted: Money available to spend, market share available from competitors, low return on self-investment, opportunities to reduce manufacturing costs, competition might steal business idea, low prices = high market share, desire to fine-tune offers from partners
    b. Information-seeking: Phone recycling, patent potential (both presumably from Arash, or maybe the former from manufacturing partner Team 5), more info about market demand characteristics (from Arash)
    c. Adaptability: Switch to flat investment/marketing rates, creation of profit model
        i. Discrepancies noted: Money now available to spend, unable to compare results to expectations this week
4. Learning outcomes:
    a. **Constrained decision-making** – Excellent; the team made decisions that were grounded in experience and knowledge gained from negotiations and results to change their business model. They are maintaining some portions of their sales model while diversifying into new

sectors of the market in the hopes of achieving a greater market share. They are also structuring deals so as to minimize any losses to themselves and to their partners.

b. **Information seeking** – Acceptable; the primary sources of knowledge this week seem to be experience and market reports. The team is also continuing to increase communications with other companies.

c. **Adaptability** – Excellent; team 9 is leveraging past successes to incorporate market insights into their business model. This is the ideal method in which companies should change.

Year #3

1. Previous Year Summary:
   a. The changes in the previous year played out as hoped and the team increased their market share and profit by diversifying into two different grade markets. Once adjustments were made for operations, profits were exactly as predicted, which demonstrates a strong understanding of the market.
2. Current year actions:
   a. Once again, the team is restructuring its marketing model in order to further diversify its market share.
   b. The team is remaining focused on producing high grade phones, but is diversifying its market share by opening up a third line to produce the lowest grade phones at reduced cost.
3. Document-level codes:
   a. Decision-making: Expand phone production, open new phone line, invest more into advertisement
      i. Potential for greater market share, market demand characteristics, profitability of existing deals
   b. Information-seeking: More market demand characteristic information from Arash
   c. Adaptability: No change needed
      i. Discrepancies noted: None
4. Learning outcomes:
   a. **Constrained decision-making** – Excellent; the team continues to demonstrate a solid understanding of market behavior and the actions of other companies. They are making wise choices in the hopes of solidifying long term profits.
   b. **Information seeking** – Excellent; The team investigated how much of the market can be captured through phone quality and pricing and adjusted their business model accordingly.
   c. **Adaptability** – Excellent; the team continues to note trends in the market and react to new knowledge regarding market capture in order to maximize profits. No change in strategy because strategy is working as intended.

Year #4

1. Previous Year Summary:
   a. The market for grade 100 phones died, resulting in extremely low sales and profit loss. The teams diversification into lower grade phones prevented them from losing even more money, however, and allowed for some sales.
2. Current year actions:
   a. Since the simulation is ending, the team has decided to cut all losses and not produce any new phones, thus no new deals. Rather, they are lowering grade 94 stock to be priced at the lowest grade phone in order to empty out all inventory and maximize funds at the end of the simulation.
3. Document-level codes:
   a. Decision-making: No new deals, severe closeout pricing on high-tech phones
      i. Constraints noted: High inventory, declining market, market demand characteristics, end of simulation
   b. Information-seeking: Market trends, advertisement rates of competitors (presumably both from Arash)
   c. Adaptability: Shift to closeout strategy, reduction of advertising investment
      i. Discrepancies noted: Declining market, suddenly very high inventory, average advertising rates of competitors
4. Learning outcomes:
   a. **Constrained decision-making** – Excellent; Given the confines of the game and the desire to maximize profits, the actions taken this year to only move standing stock is very justified.
   b. **Information seeking** – Acceptable; the team investigated future market projections to influence their decision to produce no further phones.
   c. **Adaptability** – Excellent; knowing the confines of the game and that the simulation was ending, the choice to liquefy existing stock and minimize losses is an appropriate response.

Overall

1. **Decision-Making: Excellent**
   a. Team 9 took one or more lessons away from each previous year and used this experience to solidify their business model with each iteration. Further, the team did not hesitate to change their business model within years based upon the actions of other companies. They also attempted to maximize market share through a highly diversified business model.

2. **Information-Seeking: Excellent**
   a. The team did not accept market changes at face value; they consistently researched and assessed why market changes took places and asked about projections. They also explored numerous facets of the simulation in order to understand what factors played into market capture and capitalized on this information. Finally, the team made it a point to communicate with several different companies in order to obtain the best deals.
3. **Adaptability: Excellent**
   a. This team came along way from the test years, when they weren't even assessing operating costs or projecting profits. The company demonstrated an extreme ability for growth and resilience even in a year when the high grade market dropped.