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How to Design Lean Six Sigma Simulation Games for Online Learning

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Abstract:

Simulation games (SGs) have been widely used in classrooms since they help mimic a real world operation or process in a controllable way. While simulation games are widely applied in face-to-face settings, their availability for use in online learning environments is very limited. This is an important education issue since 33.5% (7.1 million) of all higher education students take at least one online course. This number is is believed to reach up to 90% over the next 5 years as there is an increasing number of universities now experimenting with Massive Open Online Courses (MOOCs)[1].

The objectives of this paper are: 1) to identify the gap between face-to-face and online simulation games, 2) to identify key features of simulation games that enable making the learning process transformative, and 3) to develop a design-decision framework for online SGs that are as effective as their face-to-face counterparts. For these purposes, existing face-to-face and online simulation games related to lean six sigma are analyzed. Analytic Hierarchy Process (AHP), a multi-criteria decision making technique, is applied here to develop a new design-decision framework for designing educational online SGs. Through the AHP methodology, prioritized design criteria are identified. The anticipated outcome is that the online simulation games will improve student learning through active and experiential learning.

Introduction

Educational simulations can be used as a method of active learning to engage the learner in problem solving and motivating them for critical thinking resulting in more efficient learning of the underlying concepts than via a traditional one-way lecture [19]. These events can be short, as a single exercise, or a long role-playing gamethat brings in a controlled real world setting to the classroom, which may be conducted using simple materials, specially designed kits or even a computer-based multimedia simulation program. Multiple researchers is studies have confirmed the benefits of using simulations in the classrooms along with lectures and discussions [11] [14] [15].

Lean six sigma is a continuous improvement process methodology with roots originating from the lean manufacturing principles of the Toyota Production System [20] and six sigma initiatives in Motorola [8]. While debates of “which technique to use” or “which technique is better” have been ongoing, synergies of lean and six sigma methodologies made it only natural for practitioners to bring them together under the lean six sigma umbrella [4]. Lean six sigma has interested many academic scholars and has become a subject of interest for many students. Most of the major universities across the globe now offer courses, concentrations and certificate programs related to lean six sigma from introductory levels to advanced topics.

Similarly, the interest in online learning has been increasing as well. Student enrollments for online courses show a minimum 9.3% growth every year, and more than 32.0% of students take at least one course online [1]. This growth in online education can be attributed to its flexibility to enable adults to pursue higher education or specialized training without having to be away from work, at their convenient time and pace [20].

While there are many exercises and simulations on lean six sigma-related topics, most of such simulations are designed in a face-to-face (f2f) format for a physical classroom with direct participation of the students, thus leaving the increasing number of online students with no opportunity to use these simulations for active learning. The increase in number of lean six sigma online learners thus raises the need for online simulations related to these topics.

Literature Review

One of the major challenges while teaching lean six sigma concepts to people who do not have any prior experience with lean six sigma is to create a context for the students, so that they can visualize and grasp the core concepts effectively [7]. One of the major benefits of contextualized learning is that learners easily repeat it as long as they apply it in the same context [25].

Since the targeted audiences for lean six sigma education are mostly adults, it is important to align the classrooms towards problem-centered approaches for effective learning. There are some lessons to be learned based on the premises of andragogical educational approaches [6][18]. Adult learners aim their learning towards what is meaningful to them and has an immediate or near future possibility to use it, rather than learning something that may or may not be useful in the future. This factor has more weight for adults who are pursuing higher education with the aim of advancing in their current professional career path. Adults benefit more from a problem-centered orientation while learning than a didactic theoretical orientation [18]. Students also learn the expectations in a professional setting, interact and socialize with people, and understand the level of competition in those professional settings [5].

Simulations and classroom exercises implement an active learning approach, hence they are effective for adult students [22]. Classroom simulations in which students participate as groups also provide a platform for collaborative and cooperative learning, which has benefits of increased motivation, higher interactivity, fostering of social skills and improvement of metacognitive skills [25]. The simulation exercises generally provide a quick feedback to the participants, which is an essential element in any learning experience [9].

Though online education is getting increasingly popular every year, it is not free from shortcomings. There are many challenges to overcome for the efficient communication between participants in the program and setting up an effective environment for meaningful learning. As class sizes increase, the synergy level of active dialog among the participants (which is the most promising potential in online education) tends to decrease, and it eventually converges to the level of independent study [15]. Simulation and learning game sessions, in which participants actively participate as group, can help to retain this synergy.

The number of lean six sigma simulation kits and training programs have increased dramatically in the last decade, and a plethora of consulting firms have come up with their own versions of lean six sigma training programs that range from few-hour sessions to multi-day sessions. In

2003, there were about seventeen simulations used for lean training purposes by major organizations [25]. In 2010 that number shot up to more than forty [2]. Right now, a quick internet search will pop up dozens of consulting companies that provide off-the-shelf kits and training packages. A survey of games, simulations and exercises that can be used for lean six sigma classrooms has been conducted [16]. The survey identified at least 53 distinct simulations. Most of the simulations that are currently available are designed for a face-to-face classroom or offline learning. Out of the 53 simulations, only four have effective online deployments that can be used by online learners. The four Simulation games were the Dice Game [10], Beer Game (www.beergame.org), Name Game [3], and the 5S Alphabet Game (http://5salphabetgame.blogspot.ca). The literature review indicated that the gap between in class and online learning simulation games is significant. It was also observed that some of the existing online simulation games such as the Dice Game [10] were not well-designed or were not available in widely accessible online platforms [13]. This is, again, one of the main motivations of the study presented here.

Methodology

Figure 1 shows the four-step methodology that is followed in this study to design and develop an online simulation game. In step 1, a multi-criteria online simulation game design framework was developed. In step 2, we have identified a face-to-face simulation game to develop the online version for it, then we proceeded with the design and development of the online simulation game in step 3, and finally, in step 4, we tested the developed online simulation game with respect to the design criteria and compared the results with the face-to-face version.

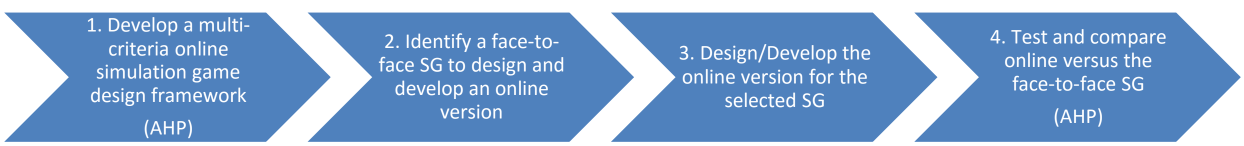

Figure 1: Methodology

As mentioned above, the focus of this study is a multiple-criteria simulation game design problem. For this purpose, Analytic Hierarchy Process (AHP) is used here to evaluate the simulation game design criteria in step 1 and the online versus face-to-face game alternatives in step 4 of the methodology.

The core idea of AHP is using multiple pairwise comparisons to compare multiple decision elements and deduce the best option available [24]. The AHP method can be also implemented to find the ranking and weights of different criteria that target users use to evaluate educational simulations. By using pairwise comparisons of different alternatives according to each of these criteria, the alternatives can be ranked. The basic process of AHP analysis includes 1. Breaking down the problem into hierarchy of goals, criteria and alternatives; 2. Collect pairwise comparison data for evaluating the weights of criteria, where a linguistic scale between 1 and 9 may be provided to the user for pairwise comparisons [23]; 3. Pairwise evaluation of alternatives based on the identified criteria; 4. Synthesis of final scores for alternatives based on its score for each criterion and the weights of corresponding criterion; 5. Checking the consistency of the judgment.

Step 1. Develop a multi-criteria online simulation game design framework

In order to design and evaluate an online SG, design criteria were established. Initially, several major criteria that appear commonly in the literature were listed and given to a sample audience (from UNC Charlotte MS in Engineering Management program) for feedback. The participants were also asked to add to the list any criteria that they believed to be important. A total of 11 participants provided inputs. This set of criteria included substantive learning, complexity, duration, customizability, timing flexibility, fun, learning objectives, discussions, engagement level, interaction, cost, pre-requisite knowledge, key topics covered, configurability, industry settings, real-world connection, graphics, interesting topic, intuitive game play, "non-boring" duration, and different player modes.

Based on the survey responses, the top five criteria turned out to be the following:

1. **Substantive Learning:** Includes number of learning objectives and subject matter of the game.
2. **Engagement Level:** Relates to fun level, participants' interaction, availability of a platform for discussion and collaborative learning, presence of competition.
3. **Complexity:** Importance of how complex or simple is the activity. How long does it take to understand the rules? Is the gameplay confusing?
4. **Duration:** The duration of game or simulation activity to achieve the learning objectives.
5. **Configurability:** How far the game is customizable? E.g. industry settings for manufacturing and services, number of people required, single player vs. multi-player setting, difficulty levels.

These 5 criteria were taken as the fundamental objectives for the design and were optimized through various means objectives, as shown in Figure 2 with the proper hierarchy of these objectives related to the fundamental objectives.

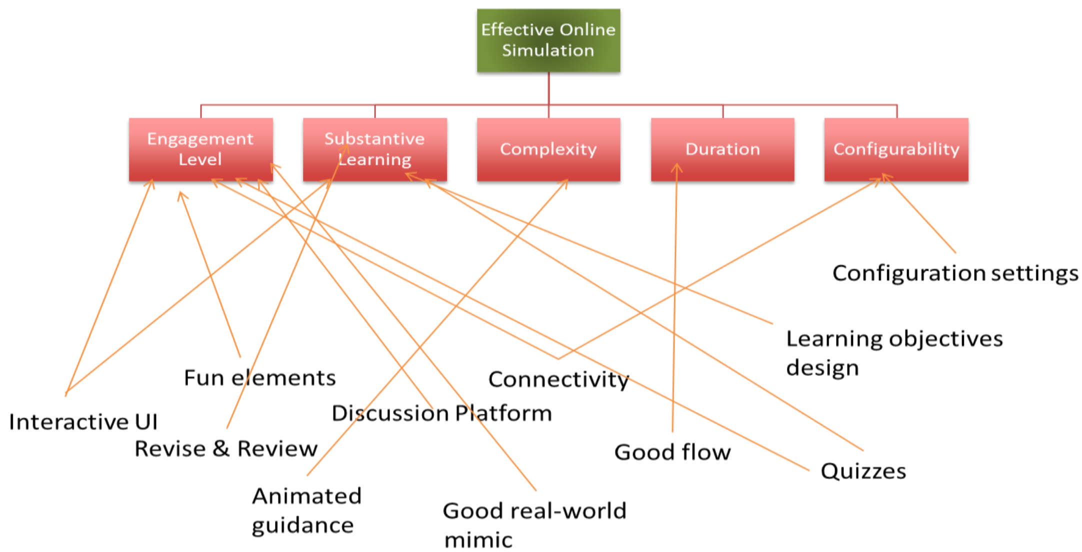

Figure 2: Fundamental and means objectives for the online SG design

Next, priorities and preferences of SG participants were identified applying the AHP technique (Table 1). As can be seen, substantive learning had the highest weight (37%) followed by engagement level (29%) and then complexity (14%), configurability (13%) and duration (7%).

Table 1: AHP evaluation of criteria for the participant group

		1	2	3	4	5		
	Criteria	Engagement Level	Substantive Learning	Complexity	Duration	Configurability	Geometric Mean	**Criteria Weights**
1	Engagement Level	1	1.04	2.4	3.76	2.16	1.83	29%
2	Substantive Learning	0.96	1	2.37	3.93	3.11	2.33	37%
3	Complexity	0.42	0.42	1	2.71	1.09	0.88	14%
4	Duration	0.27	0.25	0.37	1	0.48	0.41	7%
5	Configurability	0.46	0.32	0.92	2.09	1	0.78	13%
						Total	6.23	100%

Step 2. Identify a face-to-face SG to design and develop an online version

For the online SG design, the Dice Game was selected as the SG of interest. The Dice Game was introduced in the 1980s[12] and is a common simulation game used to teach topics related to the theory of constraints. The basic idea of the Dice Game is simulating a variance in a production setup using a die roll to determine the capacity of each workstation. The effects of process variability build up downstream and the production results in less than the statistically expected average if high process variability is present in the system [11]. Participants are assigned to different workstations in the production line and each participant rolls a die to simulate a day's capacity (Figure 3). The actual production will be the minimum of the day's capacity or available inventory. The production performance indicators are the output from the final workstation or quantity shipped to customer. This game has been selected as this seems to be a great SG to teach different lean six sigma principles, allowing discussions about constraint-based management, pull systems, cycle time, work-in-progress, and in general, the impact of variability on process performance.

Figure 3: Illustration of the production line of the dice game

Step 3. Design/Develop the online version for the selected SG

The new prototype was developed using MS Powerpoint® with embedded objects using Visual Basic for Applications (VBA) programming language. Several screenshots from the mock-up design prototype are shown in Figures 4-6. Figure 4 shows the documentation of the simulation with information on the dice that was rolled, work-in-progress, items received from previous workstation and sent to next workstation. This particular screenshot illustrates the Workstation 2 metrics and the interactive component of the simulation game where clicking on the image of the die is starting production. Figure 5 shows the summary of some production metrics such as revenue, average total inventory and the average inventory cost. This helps the user to visualize the performance of the production for each workstation as it fluctuates according to the dice roll. Figure 6 shows the screenshot where the discussion of the simulation is presented. It has a brief video lecture on it, some questions to help with a more in-depth discussion and also a thought simulating quiz question where the user will get an immediate feedback if their answer was right or wrong.

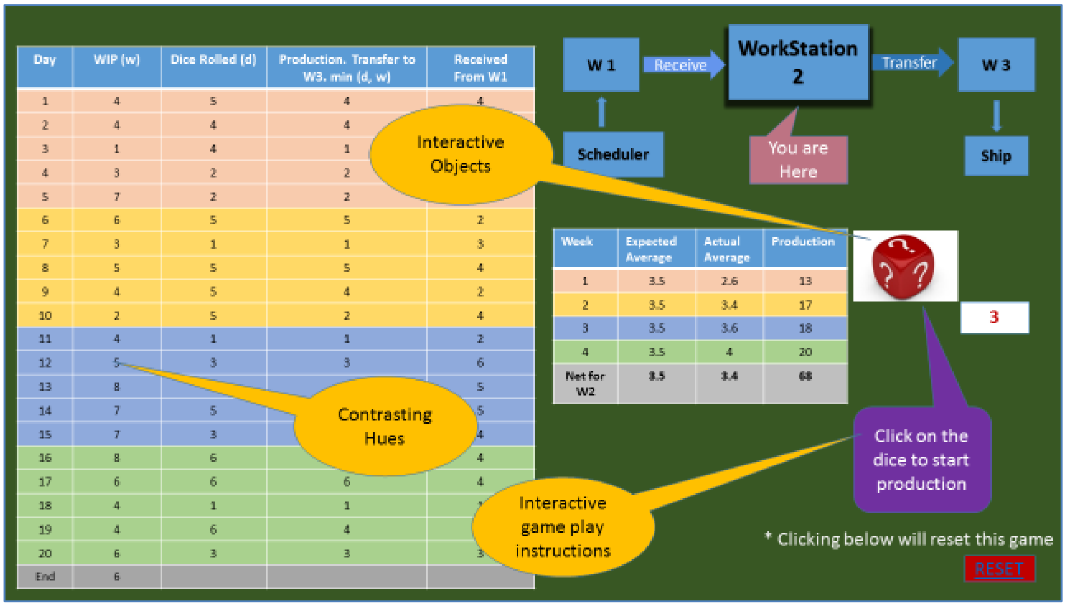

Figure 4: A screenshot of new Dice Game prototype

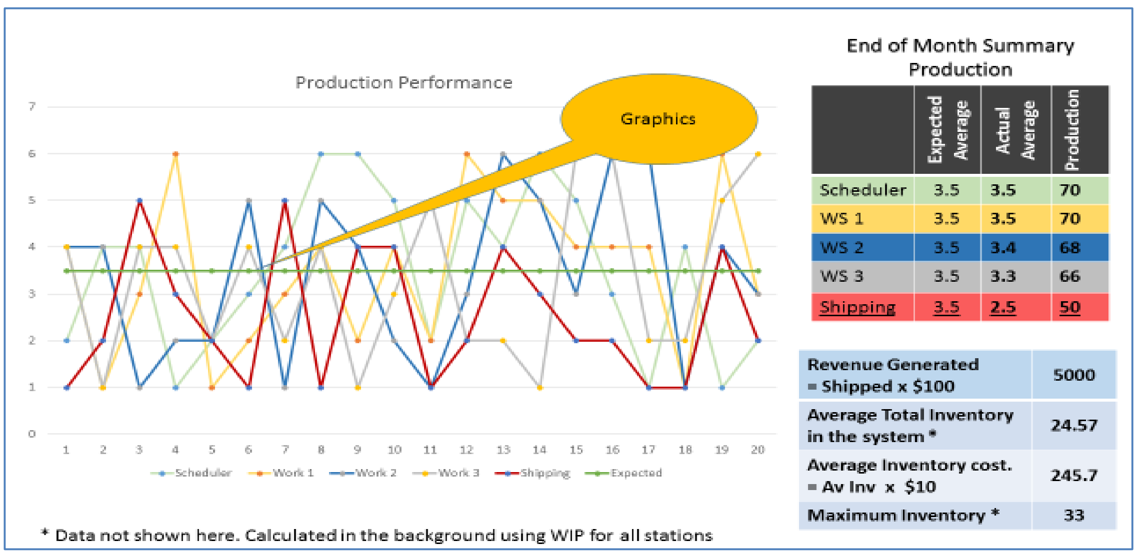

Figure 5: A screenshot of new Dice Game prototype

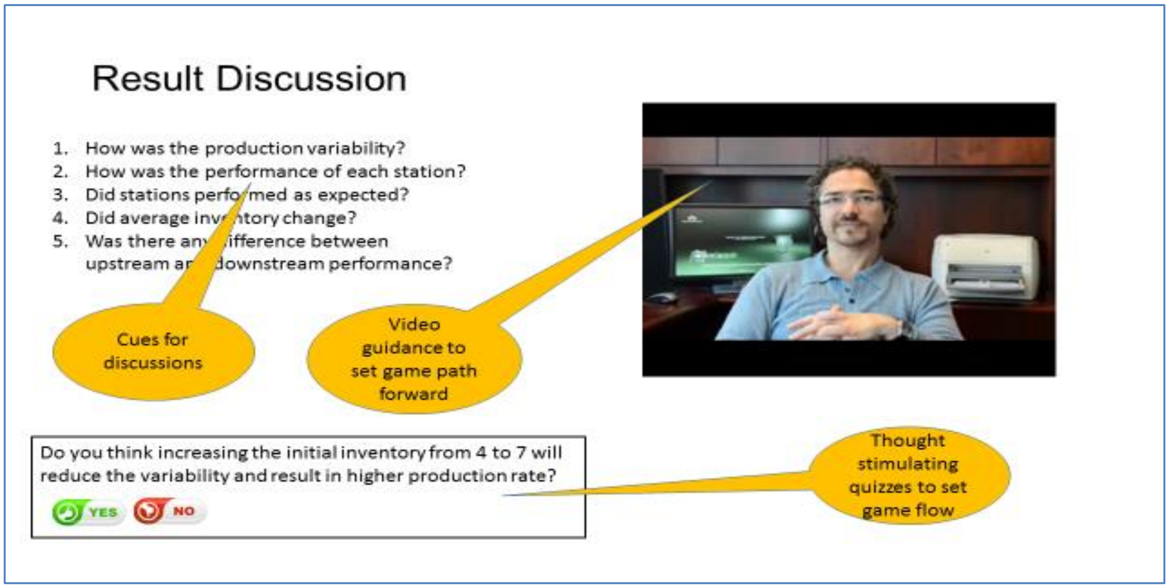

Figure 6: A screenshot of new Dice Game prototype

Step 4. Test and compare online versus the face-to-face SG

The Dice Game can be played in a face-to-face format but two computerized versions of it are currently available: a free online version [9] and an iPad/iPhone® version to purchase and download are available [12]. However, a preliminary analysis indicated that these current versions did not necessarily capture the fundamental objectives required to develop effective online simulation games as discussed earlier. Therefore, a task was initiated to develop a new online Dice Game as a prototype. With the new prototype, four SG alternatives for the Dice Game were analyzed for comparison: 1. face-to-face (f2f) classroom version, 2. the existing online version, 3. iPad application version, and 4. a new prototype. Figure 7 shows a picture of these 4 versions compared.

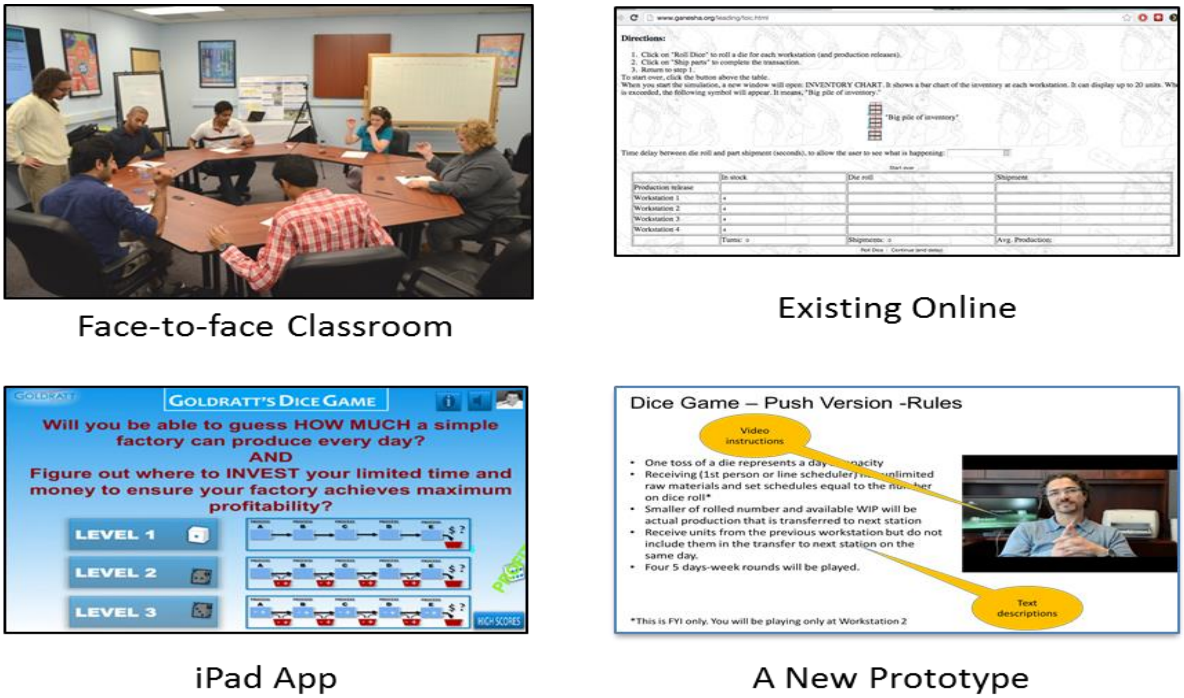

Figure 7. Dice Game Alternatives

The assessment was planned and designed to compare the existing Dice Games with the designed prototype based on the five criteria (fundamental objectives) described in Figure 2. The AHP approach was used for the comparison and evaluation purposes.

The prototype alternatives were analyzed using the AHP approach by comparing alternatives with each other with respect to each criteria, one at a time. Table 2, for example, shows the group evaluation of alternatives based on the "engagement" criterion. Based on this one criteria, the ranking of these 4 alternatives from best to worst: first: face-to-face, second: the new prototype, third: the iPad App, fourth: the existing online game. The first choice seems to be a dominant one where the score for the engagement criteria is more than twice as big as the second one, the new prototype. It is not surprising that the real life face-to-face version came out to be the best in terms of "engagement". It actually sounds really promising that the new prototype came in second place, as a better preferred version that the two previously existing online and App versions.

Following the AHP analysis for each individual participant and assessing group decisions, the final scores were obtained for each alternative based on each criterion. A weighted average of the criterion-based scores results in the final scores, as shown in Table 3. Based on this, the f2f alternative is still found to be the best among all options (with a final score of 0.46). The new prototype, the iPad App, and the existing online options have scored 0.26, 0.14 and 0.09, respectively. These preliminary results validate our initial hypothesis of a gap between f2f and online SG options. However, it has also shown that while existing simulation games are not well-designed to capture user preferences, with the new prototype, it is possible to try to close this gape. As these preliminary studies demonstrated, it is possible to develop a better SG closer to the f2f options. Although this current prototype had limited features, further research is proposed here to help develop SGs that are more comparable to f2f versions.

Table 2: Sample AHP group evaluation of alternatives for the engagement criteria

Evaluation of Alternatives based on Engagement		1	2	3	4		
		Face-to-face	Existing Online	New Prototype	iPad App	Geometric Mean	**Alternative Scores**
1	Face-to-face	1	5.81	3.18	3.69	2.87	56%
2	Existing Online	0.17	1	0.44	0.72	0.48	9%
3	New Prototype	0.31	2.28	1	2.59	1.17	23%
4	iPad App	0.27	1.38	0.39	1	0.62	12%
					Total	5.14	100%

Table 3. Comparison of Dice Game Alternatives Based on AHP Analysis Results

		Criteria & Weights					
		Engagement Level	**Substantive Learning**	**Complexity**	**Duration**	**Configurability**	**Final Score**
		0.29	**0.37**	**0.14**	**0.07**	**0.13**	
Alternatives	**Face-to-face**	0.56	0.45	0.33	0.12	0.58	0.46
	New Prototype	0.23	0.28	0.27	0.35	0.24	0.26
	iPad App	0.12	0.14	0.16	0.20	0.12	0.14
	Existing Online	0.09	0.08	0.10	0.17	0.09	0.09

Summary and Conclusions

While educational and simulation games are nothing new in the traditional classrooms, online students usually have much less opportunities to enjoy the benefits of these games, as these games do not usually have their online versions. To fill this gap between the existing face-to-face and online games, a multi-criteria decision analysis framework was used to identify the key features of these games that enable the online learning process transformative. Once these key features are identified, a new version of an online game can be created focusing on these features in the design.

In this paper, several versions (face-to-face, online, iPad/iPhone app and a new simulation version) of a lean six sigma game, namely the Dice Game, were examined and compared here to design an online simulation version of the game that is comparable in effectiveness to its face-to-face counterpart. To identify the important criteria that make this new version compatible with the face-to-face version, a multi-criteria decision analysis technique, AHP, was used.

The findings of this study can be summarized as follows:

- There seems to be a gap between face-to-face and online simulation games, however, as it was demonstrated through the dice game example here, it is possible to identify elements of this gap and try to close this gap with the design of a new simulation game that takes into consideration these important elements.

- There were five criteria identified as key elements in the design of the simulation games: the two most important criteria seem to be substantive learning and engagement level, while complexity, configurability and duration are much less important.

- A new online prototype simulation of the Dice Game has been developed with these key criteria in mind, and all of the Dice Game versions (face-to-face, online, iPad/iPhone app and the prototype simulation version) were evaluated. While the face-to-face game had the best overall score, the new online prototype got the second best overall score, so this version may be a good start to develop the online version of this game that is comparable with the face-to-face-version in many key aspects. It is also interesting to note that in one aspect, duration, the new online prototype got the highest score. However, that is the least important criteria among all five criteria identified.

While these results are promising, there are limitations of this study that need to be addressed in future extensions of this research:

- The sample size was rather limited for the preliminary simulation game prototype assessment, as 11 students participated in evaluation of the criteria and the different versions of this game. A larger sample would be desirable in future studies to confirm these results.

- The sample only included graduate students, while other stakeholders such as undergraduate students or instructors were not part of the initial evaluation. In the future, it would be very important to include other stakeholders in the study as it is possible that they have a different set of preferences of the key elements of the game.

- Only one game, the Dice Game was evaluated in this study for illustration purposes. Other games can be developed and studied in the future as well.

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