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***Abstract*— A complete learning object with scenario-based simulation game and accompanying materials, which allows self-directed learners to learn and apply the theory, concepts and calculations for capacity planning, in the hospital beds capacity planning scenario in Singapore, was designed, developed and implemented. It guides the learners through the key considerations for capacity planning, the computation of actual capacity needed, deciding the timing for capacity increments, as well as the economies and diseconomies of scale when adding capacity. All the learnings are applied in a scenario where the learners make decisions on how much and when to add hospital beds to existing hospitals, and when to add a brand new hospital, to manage the bed crunch problem in Singapore, in the face of an aging population. We have successfully demonstrated how a scenario-based simulation game with high level of interactivity, can engage and motivate self-directed learners to learn at their own pace and practice their knowledge acquired by immersing them in a well-known context. A high percentage of the learners found the learning object engaging and motivating, and effective in their learning. Between the 2 runs, some improvements were made in response to the suggestions made by students from the first run, which resulted in better results achieved in the 2nd run.**

I. Introduction

Very often, schools teach operations management related topics using traditional face-to-face classroom setting where the instructor will go through the theory, concepts and the required calculations to teach learners how to make decisions to improve the efficiency of the operations in terms of reducing cost, reducing time, increasing revenue and increasing quality. Learners are often provided with slide materials to follow along in class while listening intently to the instructor. In some cases, class exercises and tutorial questions will be provided to allow learners to have more practice opportunities, so as to reinforce the learning. Such a setting would be ideal if all the learners learn at the same pace, able to concentrate 100% during class, and absorb everything that the instructor has taught.

However, education practitioners like us know that the ideal situation can only remain as ideal. Each and every learner is a unique individual who learns at his or her own pace using his or her own style. Some learners may be able to learn well by just listening to the instructor teach once, while others may need the instructor to repeat, may be more than once, to be able to fully grasp the learning.

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The objective of designing and developing the interactive scenario-based simulation game for this capacity planning topic, is to allow individual learner to learn at his or her own pace, repeat the materials as many time as desired, and take time to apply the learning to a real case. Self-study asynchronous e-learning also has the potential to customize learning to the unique learner - similar to a one-on-one tutoring with human mentors as reported in [1]. In additional, e-learning can accelerate learning by immersing learners in authentic environments that require them to complete tasks faster than they could do so in the real world. This scenario-based e-learning is defined in [2] as "a preplanned guided inductive learning environment designed to accelerate expertise in which the learner assumes the role of an actor responding to a work-realistic assignment or challenge, which in turn responds to reflect the learner's choices". The learner can perform the necessary calculations using Excel spreadsheets, and then make the decisions, in this case, adding beds to existing hospitals and adding a brand new hospital, at different times, to tackle the bed crunch problem in the Singapore, while keeping in mind the key learning points related to capacity planning.

The rest of the paper is organized as follows. Section 2 discusses the relevant literature on simulation games, particularly in the teaching and learning of operations management topics. Section 3 describes the overall design of the complete learning object, while Section 4 describes the scenario-based simulation game. Section 5 discusses the learners' feedback and improvements made, while Section 6 provides the conclusions.

II. Literature Review

There are several past literatures that report on using simulation game to teach operations management topics and their related decision making processes. The *Beer Game* [3] which was developed at the Sloan School of Management at MIT in the 1960s is a well-known simulation game that aims to help learners experience and understand the bullwhip effect in a supply chain. Recognizing the limitations of the *Beer Game*, the *Lean Leap Logistics Game* [4] was designed to foster collaboration using multi-stage supply chain simulation, so that the game participants can gain more realistic insights into the scheduler behavior, scheduling decision making, prioritizing improvement activities and supply chain dynamics.

Another scenario-based supply chain simulator to simulate a network of facilities and distribution systems to carry out procurement and transformation of materials from manufacturer to customer was developed by [5]. A flexible simulation game called SIMPLE (Simulation of Production and Logistics Environment) was developed by [6] to teach inventory management, capacity management, pricing determination and negotiation, and information-sharing between players. It can be played in a single- player single-tier scenario (Manufacturer mode) or multi-player multi-tier scenario (Supply Chain mode). Parameters can be flexibly set to allow instructors to design different games for different teaching stages.

Other simulation games include the *Dice Game* [7] to teach Kanban systems, *Goldratt's Game* [8] for teaching capacity utilization, bottlenecks and queues in production processes, *Lean Typing Game* [9] and *Logistic Game*[TM] [10] for teaching topics on lean manufacturing.

The impact of simulation game on operations management education was investigated by [11]. They defined pedagogical simulation games as "challenging interactive pedagogical exercises, wherein learners must use their knowledge and skills to attain specific goals, played within an artificial reproduction of a relevant reality". They presented a simulation game, HECOpSim, which puts the learners in the context of a single manufacturer which manufactures two products, to plan the sales forecast, and decide on the amount of raw materials to purchase and number of products to produce, taking into account hiring and layoff plan. Their results showed that "simulation games are more effective when learners have to develop decision-making abilities for managing complex and dynamic situations". In their paper, they also tabulated other works which attempted to measure the effectiveness of using simulation games to achieve cognitive-based, skills-based and affective-based learning outcomes.

The development of a plug-and-play interactive game which allows existing games to be expanded or customized to meet various teaching needs in lean management, based on a factory production line simulation was done by [12]. The goal is to reduce learning and resource overheads required to prepare and run different simulation games for learners of different levels. The paper described the plug-and-play framework to guide the integration of different elements or modules (e.g. SMED, Poka-Yoke, Kanban) and setting of variables, functions and rules. Their initial results showed that the plug-and-play framework can support progressive learning from concepts, to tools/techniques and to application. Although the platform has been tested only once, the response from the learners were positive.

Most simulation games allow the learners to apply the knowledge acquired while playing the game, and the theories and concepts in the OM topics are taught separately via traditional means. Our work differs with the earlier works in that it is a self-contained and integrated learning package which includes an online learning object that covers the theories and concepts on capacity planning, its integrated scenario-based simulation game, its accompanying course content and the Excel spreadsheet for computation. It attempts to demonstrate the effectiveness of self-directed learning and application in a real-world scenario to make complex decisions, in the context of hospital bed capacity planning in Singapore.

A comprehensive study of 222 OM specific and OM related games was completed by [13]. It was found that the OM specific games did not cover beyond introductory OM issues, and are predominantly in quantitative manufacturing-oriented games, whereas the trend is to move towards more qualitative service-based subjects in OM content. We believe that we are the only OM related simulation game which is focused on healthcare service problem, instead of the predominantly supply chain and manufacturing problems, and our offering is by far the most self-contained, integrated, and perhaps even most visually appealing.

III. Overall Learning Object Design

In designing the learning object, we started with defining the learning outcomes and how each learning outcome is achieved through the course material and the simulation game within the learning object. The learning outcomes include the ability to achieve the following:

- List the major considerations when planning for capacity
- Explain where, what, how much and when decisions which are related to capacity planning
- Describe the difference between rated capacity, expected capacity and actual capacity
- List factors affecting actual capacity
- Compute actual capacity needed
- Justify which policy to choose when deciding timing for capacity increments
- Explain the long and short term economies of scale when increasing capacity
- Explain the diseconomies of scale when increasing capacity

The learning object and its integration with the necessary supporting learning materials, simulation game, Excel spreadsheet and PowerPoint slides, are depicted in Figure 1 below. The learning object presents the content with interactive activities, like click-and-learn, and drag-and-drop. Learners will fill in the critical missing words in the PowerPoint slides course materials as they go through the learning object. Learners' feedback shows that this helps them to pay attention to the key points and aids memory.

The simulation game is highly interactive where the learners can enter their decisions, based on their computations performed on the downloaded Excel file, and the system re-computes the results real-time to provide a final results summary. Through this simulation game, the learners can apply the theories, concepts and computations learned directly into a real scenario in order to test their understanding and achieve the learning outcomes. Interested reader can request for a login username and password from the authors to access the learning object. The flow of the simulation game in Figure 2 illustrates how the learners interact with the game by entering the decisions and the system will provide real-time feedback on the results achieved.

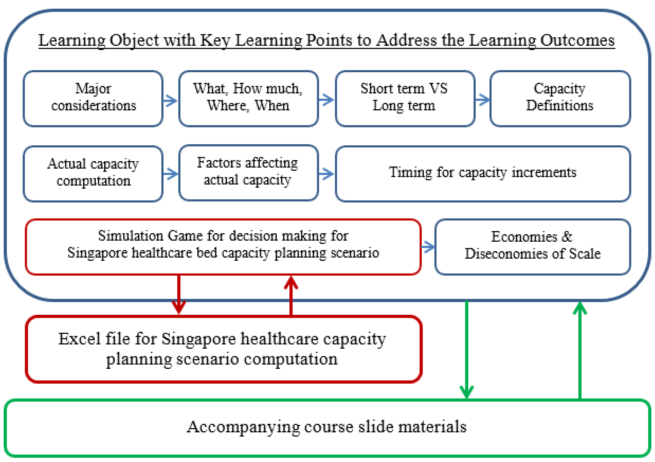

Figure 1: Overall Learning Object Design

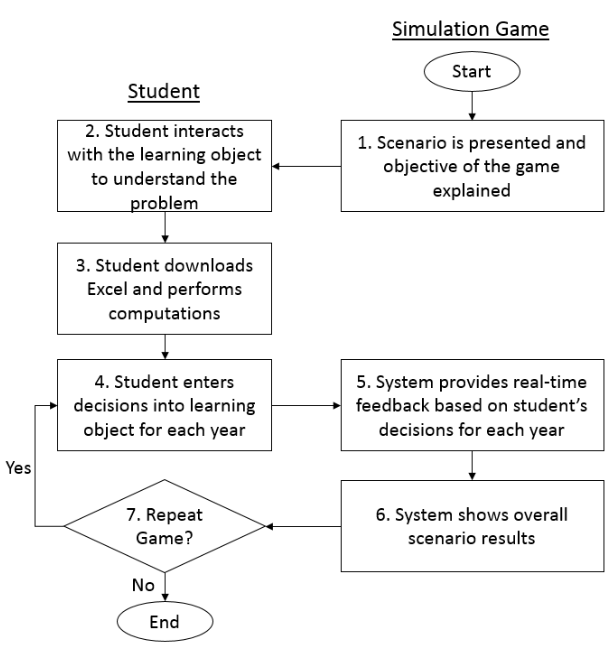

Figure 2: Flow of Simulation Game and Learner's Interaction and Input

IV. SCENARIO-BASED SIMULATION GAME

The simulation game is designed based on the actual Singapore's healthcare system using real data, with some minor necessary adjustments and estimations due to the lack of information. The learner will play the role as a senior officer at the Ministry of Health who has been tasked to study the current and future planned capacity of the public general hospitals and to determine if it is sufficient to satisfy the growing needs for 7 years, from 2014 to 2020. If the capacity is not sufficient, the learner has to decide which existing hospitals should add an additional 50 beds and when to add these beds, and also to decide in which year to add a new 2000-bed hospital. Such decisions can only be made by performing detailed calculations using an Excel spreadsheets with some basic data collected and estimated.

The simulation game enters the scenario with showing the learner a chart that plots the projected demand and supply of beds, and overall utilization rate from 2014 to 2020, in Figure 3. Learners can click on any selected year on the chart and the associated table below reflects the beds supply and demand and utilization rate for each of the 8 hospitals and the overall total figures. Utilization exceeding 100% will be highlighted in red font so that learners can pay attention to them. To begin solving the capacity planning problem, learner will be prompted that the objective is to ensure that overall utilization rate does not fall below 80% and does not exceed 100%. The utilization rate range can be easily altered by making the necessary changes in the HTML code and JavaScript of the learning object. Learner can download the Excel file with the basic data to start working on the computation.

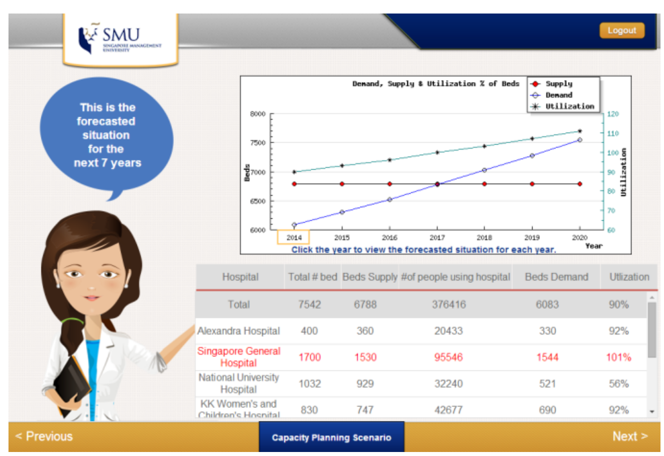

Figure 3: Forecasted Demand, Supply & Utilization % of Beds

Using the data given, the learners will be guided step-by-step on how to perform the computations using the Excel spreadsheet. The learners can take their time to formulate the Excel model and perform the calculations, including computing population growth rate, allocation of population to each hospital, demand and supply of hospital beds. Once the learner has completed the modeling and computations, they can use the Excel spreadsheets to test out different decisions by adding beds to different hospitals in different years and also to test the adding of a new hospital in different years. After careful evaluation of the different possible solutions, the learners will return to the simulation game to enter their decisions, which include deciding the year to add an additional 50 beds to any of the existing hospitals, and the year to add the new 2000-bed hospital (see Figure 4). After each decision is entered, the system will compute the new bed supply numbers and utilization rates, and the table on the screen will be updated accordingly in real-time. Such a live computation provides a real-time feedback to the learners on how their decisions affected the utilization rates of the hospitals and also the overall utilization rate.

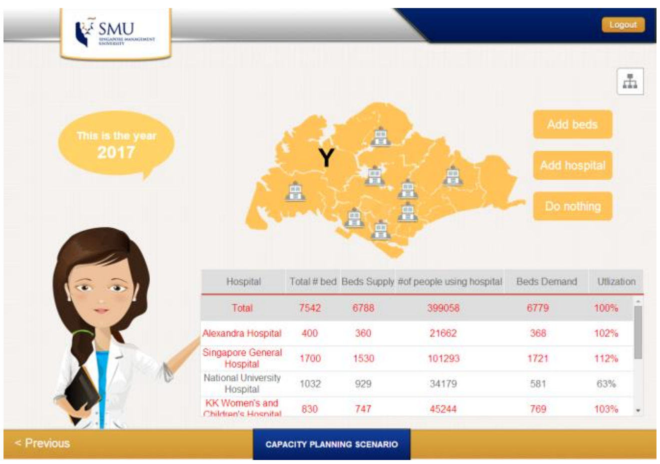

Figure 4: Decision Making for Each Year

After the final decision is entered, the system will plot a new chart (Figure 5), showing the total bed supply and demand, and the overall utilization rate, based on the learner's decisions. If the overall utilization rates for all years are within the range of 80% and 100%, the learner would be deemed to be effective in his or her decision making. Learner can click the "Try Again" button to erase all earlier decisions, and enter other decisions for his or her new attempt.

There are three possible resulting scenarios designed into the simulation game. The system will determine 2 values, A and B as described below.

- A = Count the number of years where overall utilization > 100%.
- B = Count the number of years where overall utilization is < 80%

The three possible resulting scenarios are described below:

- Scenario 1 – When A > 0, then message will be "You have added the capacity too late. For some years, the overall capacity is insufficient to cater to the growth in patients' need for beds."
- Scenario 2 – When A = 0 and B = 0, then message will be "You have provided a great capacity plan. The adding of capacity is well managed and utilization rate is optimal."
- Scenario 3 – When A = 0 and B > 0, then message will be "You have added too much capacity too early. There are some years where the utilization rate is below 80%."

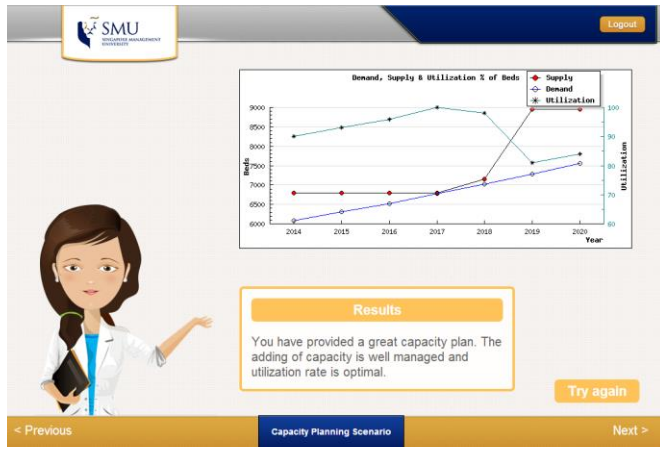

Figure 5: Forecasted Demand, Supply & Utilization % of Beds Based on Learner's Decisions

V. LEARNERS' FEEDBACK AND IMPROVEMENTS

Two batches of learners have used this complete learning object to learn about capacity planning. 30 learners in summer 2014, and another 37 in summer 2015. A survey was conducted after each delivery, and some of the key survey questions and the responses related to pedagogy and learning outcomes are given in Table 1.

Overall, the results are positive and the second delivery has shown significant improvements over the first delivery, in all the questions, except question 3 which has the same results. The improvements are due to the changes that were made to the learning object which are discussed in the later section.

Comparing the responses between question 1 and question 2 for 2 batches, we can see that a large proportion of the learners (72% and 93%) started with none or little knowledge in capacity planning, but after using the learning object with the scenario-based simulation game, an even larger proportion of the learners (87% and 94%) reflected that they have gained some or a lot of knowledge in capacity planning. This clearly demonstrated the effectiveness of the learning object.

In addition, a large proportion of the learners (79% for both batches) found the supplementary slides effective or very effective in their learning of the topic. This shows that apart from learning from online sources, learners would like to have materials (in the form of accompanying slides or books) which they can use to supplement their learning. A very high percentage of learners (92% and 94%) found the Singapore hospital scenario effective or very effective in their learning of the topic. This shows that learners like to work with a scenario which they are familiar with. Some learners were non-resident of Singapore, but this factor did not affect the effectiveness of the scenario in terms of learning effectiveness.

Finally, very large proportion of the learners (71% and 88%) agreed that the learning outcomes of the topic were achieved, and also very large proportion of the learners (67% and 85%) found the overall design of the learning object effective or very effective.

Survey Question	First Batch	Second Batch
1. Rate your knowledge on capacity planning before using the learning object.	72% "None" or "Little"	93% "None" or "Little
2. Rate your knowledge on capacity planning after using the learning object.	87% "Some" or "A Lot"	94% "Some" or "A Lot"
3. Do you find the supplementary slides effective?	79% "Effective" or "Very Effective"	79% "Effective" or "Very Effective"
4. Do you find the Singapore hospital scenario effective for your learning?	92% "Effective" or "Very Effective"	94% "Effective" or "Very Effective"
5. Do you agree that the learning outcomes of the topic are achieved?	71% "Probably Yes" or "Definitely Yes"	88% "Probably Yes" or "Definitely Yes"
6. Do you find the overall design of the learning object effective?	67% "Effective" or "Very Effective"	85% "Effective" or "Very Effective"

Table 1: Quantitative Responses of Some Key Survey Questions

Qualitative feedback comments from the learners on what they liked about the learning object and its simulation game include:

- You can ***repeat as many times*** as you want.
- The added ***interactivity makes things more interesting*** than learning through readings and notes
- The concepts are ***easier to understand*** with the exercise
- ***Immersive***
- It is ***easy to navigate, easy to review*** the screen by clicking the next and previous buttons, and I can explore and make decisions based on the information
- I like that the ***scenario-based learning object*** allows us to apply what we learn
- Learning from online gives students the ***flexibility to learn*** as and when there is Internet access
- It engages us and ***makes us think***
- Learning through ***interactive scenario*** is interesting
- I found the ***matching/fill in the blanks bits pretty useful*** - forces me to pay attention and aids memory.

Qualitative feedback comments from the learners on the possible improvements include,

- The online learning object is useful and good, however it is ***not interactive enough***. In addition, I can't discuss and ask questions.
- Learning through interactive scenario is interesting but there is a ***challenge to get further clarification*** without a way to post query and obtain some sort of feedback.
- Most of the ***interaction was rather superficial***, e.g. click on labels for definitions to come out... I found the matching/fill in the blanks bits pretty useful - forces me to pay attention and aids memory.
- It would be nice if you could ***provide the best solution*** as well….If you want to keep for enthusiastic students only then unlock that option after 4-5 attempts. It will make students happier.
- To ***add some voice lecture*** to explain more about the detail. It would be better to have voice or animation
- ***More instructions*** can be stated upfront to make the scenario exercise clearer. At the same time, there were no options to change the decision once the decision was made for any one year.
- May need to ***include a voice-over*** in future. Have more short Q&As/fill in the blanks/answer matching slides after each key concept to help students remember what they just read. Less involved example/exercise for students to practice on. ***Indication of length of module and current progress***.
- ***Build the excel sheet*** inside this platform!!
- ***Online forum*** for discussing questions.

Based on the qualitative feedback comments provided, several improvements were added into the learning object as follows:

- A chapter selection page is provided at the start so that learners can view the different chapters in the learning object, the topics covered for each chapter and the estimated time taken. To encourage learners to complete all the chapters, only chapters which they have completed will be enabled for selection. Learner can continue from where they left off, or to repeat any of the chapters they have previously completed
- A progress bar in the form of a syringe is provided so that the learners can know their own progress.
- We note that learners do not feel connected to the learning object when there is total silence. On the other hand, too much voice over can be disturbing too. So a voice over is added to read out the instructions and key messages only at the critical points.
- We have recorded 9 video snippets on the computations using the Excel sheet, as well as the recommended solution to the problem. This will allow the learners to learn from the videos in case they could not obtain the solutions.
- Currently, there is already asynchronous online discussion forum where the learners can post questions and answers can be provided by the instructor or their peers. However, learners still prefer real-time feedback, much like during a face-to-face class session. In order to facilitate the real-time feedback, one way is to stipulate a common time where learners can go through the learning object and post questions, with the instructor or the teaching assistants on stand-by to provide responses. This method has its pros and cons. It will provide instant feedback to learners and will work fine when the learners and instructors are in the same or similar time zone. However, when time zone is an issue, it will become harder to implement.
- The particular feedback on building the Excel sheet within the learning object platform will be technically challenging to implement, and thus will not be added into the learning object.

VI. CONCLUSIONS

The topic on capacity planning using the interactive learning object and its simulation game were delivered to our 3rd and 4th batch of Master of IT in Business (Analytics) students in summer 2014 and summer 2015. The earlier 2 batches of students learnt this topic using the traditional face-to-face classroom setting, and the feedback was that the lesson was not as interesting as it was delivered via the traditional one-directional lecturing mode.

The learning object aims to make learning more interesting and with different levels of interactivity. The simulation game was developed based on the Singapore healthcare context which is easily understood by the learners, and even if the learners are not from Singapore, as it is a global problem that anyone can easily understand and relate to.

The feedback from the two batches of students were encouraging with a high percentage of the students who found the learning object and its simulation game appealing, highly motivating to use and engaging. A similarly high percentage of the students also found the healthcare scenario, and the supplementary course material slides effective for their learning. From the instructor's point of view, after delivering the same topic four times in the same course, the students' engagement level and learning enhancement were definitely much improved, as compared to the first two batches of students.

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