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Using Kaizen Process to Improve Learning Outcomes Manufacturing Simulation Projects

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Abstract
Simulation is a core course for many Manufacturing Engineering related programs. This course introduces discrete event simulation methods with emphasis on application in manufacturing systems or service systems. The topic of queueing theory in operations research is used to illustrate the importance of simulation as a problem-solving tool. Concepts and techniques of simulation modeling are covered. It also requires statistical concepts and techniques to obtain representative data, to apply the data and statistics to the modeling, and evaluate the results. To help the course learning, term projects are usually assigned to the students. The authors have been teaching this course for over ten years. Kaizen process has been used in the Simulation course project to continuously improve learning outcome. This paper details Kaizen process, which includes 1) identification of problems, 2) displaying of problems, 3) action to clear problems, and 4) check and acknowledge, in improving student learning in simulation project. This continuous improvement process can be used not only for teaching Simulation course, but also be referred for other course education.

1 Introduction

Discrete event simulation is an important tool to support manufacturing industry for continuous improvement of efficiency, cost, cycle time, and staffing, etc [1]. Many Manufacturing Engineering related programs offer the Simulation as a core course to students. At Virginia State University (VSU), this course introduces discrete event simulation methods with emphasis on application on manufacturing. The topic of queueing theory in operations research is used to illustrate the importance of simulation as a problem-solving tool. Concepts and techniques of Arena® simulation modeling are covered. It also requires statistical concepts and techniques to obtain representative data, to apply the data and statistics to the modeling, and evaluate the results. The desired course outcomes for the learning outcome for Simulation course at VSU are below:

1. To introduce students to simulation of discrete event manufacturing and logistics systems.
2. To present the basic statistical techniques behind computer based simulation models.
3. To learn to formulate logistics and manufacturing problems suitable for analysis using simulation models.
4. To translate logistic and manufacturing problems into computer simulation models using simulation software packages.
5. To exercise simulation models for design and operational optimization purposes.
6. To introduce the use of statistical analysis for interpreting the results of simulation modeling.

When evaluating students learning outcomes in the Simulation course, it is difficult to demonstrate broad modeling concepts and skills during a final exam. Thus, students are required to using the comprehensive knowledge that they received in the class to achieve a term project. The stages of Simulation project is as below, and the grading for each portion of the project is tabulated in Table 1.

1) Proposal. Students are required to submit a project proposal on the systems to be simulated. The proposal should also include process flow diagram on the system, and then identify project goal with performance measures (cost, resources utilization, and waiting time, etc.).
2) Data collection and input analysis. Collect the data on process flow, inter-arrival times, processing times, travel times, operator work schedules etc. Then apply the "Input Analyzer" in the Arena® to identify the statistical patterns and parameters about the data. Students should know how to use p-values and errors to fit the data to a certain probability distribution, also be able to make reasonable assumptions for unobserved random variables.
3) Initial modeling. With collected data and process flow, exercise Arena® modeling to simulate the proposed system, pay attention to the statistical validity of the output results. For example, they should do some statistical analysis of simulation output results, and then identify potential improvement to the system operation through modeling and result analysis.
4) Improvement modeling. Alternate at least one configuration or operating policy to improve the system in terms of project goal, re-build the Arena® model for improvement analysis.
5) Experimentation and output analysis. Use the "Output Analyzer" or "Process Analyzer" in the Arena® to do thorough, systematic and statistical comparisons between different configuration scenarios. The output results and comparison should be presented into tables/graphs.
6) Report writing and final presentation.

Table 1: Project Grading Scheme

Item	Points
Modeling	
Problem & System Description	5
Key Data Collection and Analysis	10
Arena Model	25
Experimentation & Output Analysis	15
Conclusion	10
Writing	
Written Report	20
Presenting	
Class Presentation	10
Attendance during the presentations	5

Kaizen, originated from the Toyota Production System [2], has been widely applied on continuous improvement of manufacturing industry. Enlightened by the Kaizen's industrial applications, the author applied the Kaizen process in the Simulation course project. This paper details the Kaizen process of identification of problems, displaying the problem, action to clear the problem, and check and acknowledge in improving student learning in simulation project.

2. Applying Kaizen process to the simulation class

The PDCA (plan-do-check-act or problem finding-display-clear-acknowledge) [2] is applied in the class teaching. As illustrated in Figure 1, the PDCA follows the procedure of: 1) standardize an operation and activities, 2) measure the operation, 3) gauge measurements against requirements, 4) act to meet requirements and increase performance, 5) standardize the new, improved operations, and 6) continue cycle.

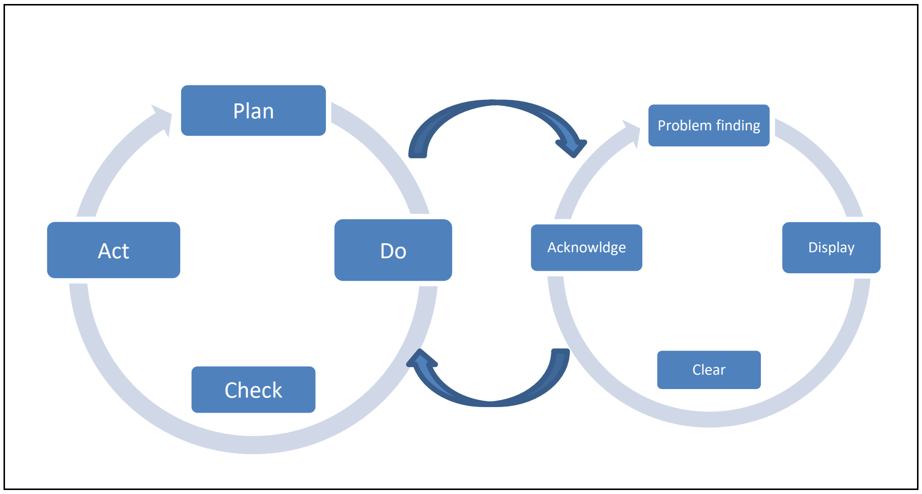
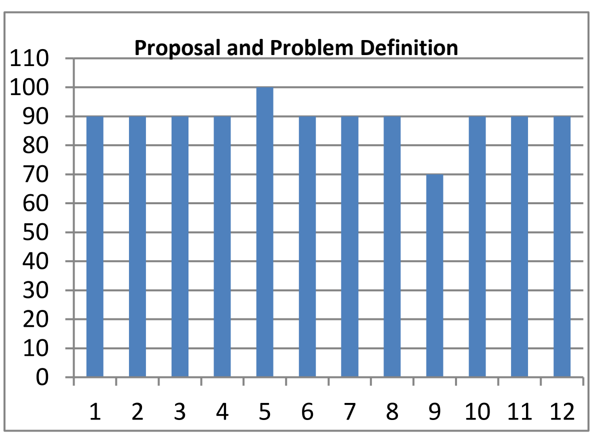


Figure 1. PDCA Cycle in a Kaizen Process

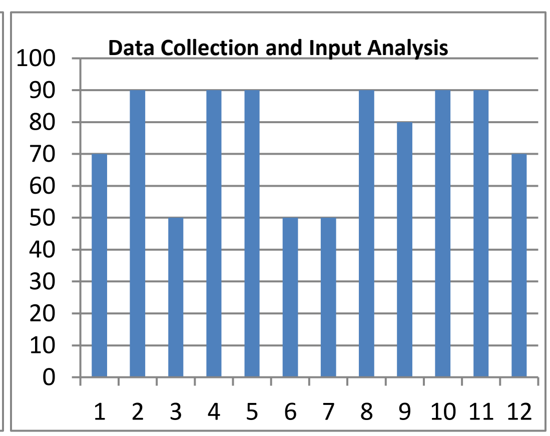
2.1 Plan and problem finding

The course project in Simulation has been standardized the procedure of project activities, also decided the grading rubric for each procedure as aforementioned Table 1. During the classes, the instructor gauges students' learning outcome by: (1) class observation, and (2) document analysis [3]. The instructor observes the class performance including class participation, homework submissions, quizzes, and presentations during the semester. These observations are real-time recording of implementing Kaizen in the Simulation course. It provides important feedback for the instructor to adjust the teaching in classroom. This documentation included proposals, Arena models, final project reports, and final presentations. The document analysis validates Kaizen through multiple sources of data collection. It provides carefully planned endeavors for the next round of Kaizen process.

Figures 2 (a) through (e) are the project evaluations of 12 students' final projects in the Fall 2012. In these plots, the X-axis is each individual student, and the Y-axis is their grades. From the observation and document analysis, problems and concerns were identified on different stages of the project. The learning outcomes on: 1) data collection and input analysis, 2) statistical analysis of output results, and 3) report writing, need to be improved.



(a)



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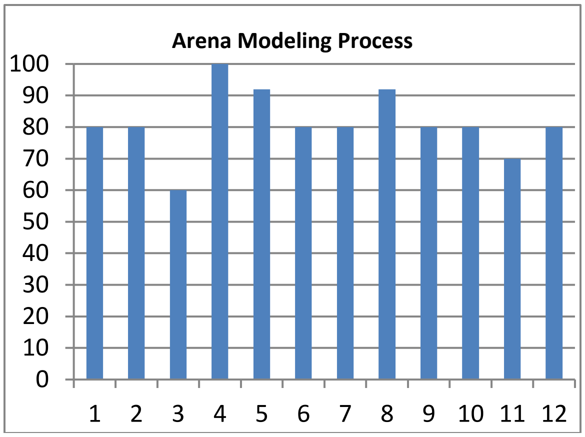

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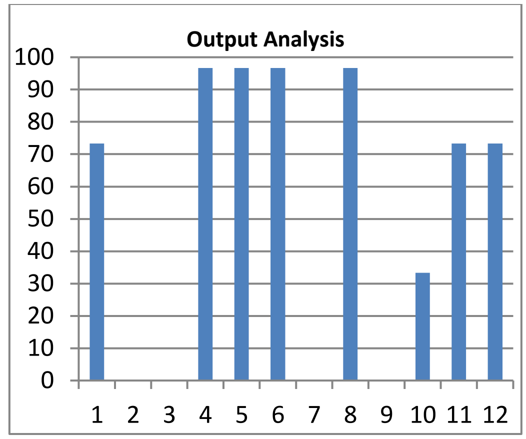

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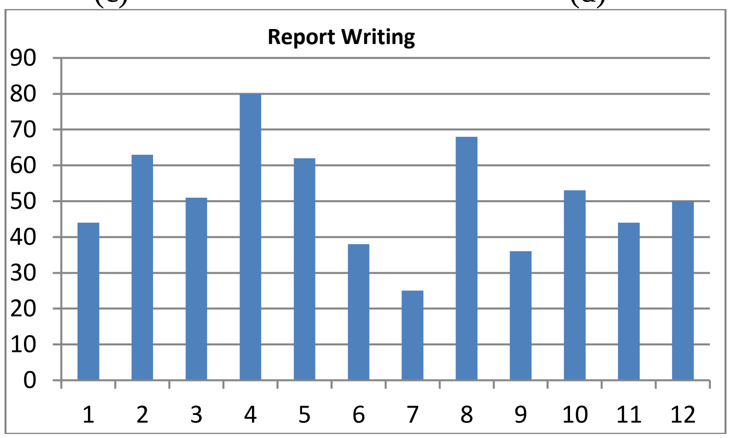

(e)

Figure 2. Performance Measure on Students Projects

Data collection in simulation modeling is to find the information for logic/structural modeling (process flow) and quantitative modeling (inter-arrival time, process time, etc.) in simulation. The data collection procedure is time-consuming, also expensive [4]. The system that being modelled sometimes does not exist yet or may be non-stationary. The difficulty in data collection is a common problem in system simulation. In the course teaching, the students who did well on this subject usually have sufficient access to the system and data. For example, they have been employed by companies doing the work related to their simulation projects.

Output analysis. Students are required to analyze the simulation results using either the "Output Analyzer" or "Process Analyzer" in Arena®. The purpose of output analysis is to aware students about the nature of "random in random out" (RIRO) in discrete event simulation. Students should also be able to explain the simulation results, identifying the root cause of improvement on system operation. In projects submitted by students in the Fall 2012, some students even did not statistically analyze their simulation results at all.

Further, simulation projects were assigned as individual work in the Fall 2012. When students started writing the final report, it was after the Thanksgiving and in the final week of VSU. Some project reports were rushed in the last minute with poor writing quality.

2.2 Act to clear the problem

The following actions and suggestion have applied in the Simulation course to clear these identified problems in the following years.

Action 1: Considering this as an individual project, the workload may be heavy since the student need to identify the system, collect data, finish modeling, do statistical analysis and comparison, and write a technique report. We grouped two students to deliver a project; they will have more discussions and help each other, thus achieving a better performance.

Action 2: Emphasize more on the "Statistical Analysis of Output from Terminating Simulations" chapter in the Manufacturing Simulation course. That helps students better perform in output analysis of their simulation results.

Action 3: Practice students' analysis skills in the homework assignments, ask students to submit not only the simulation models, but also short descriptions on interpreting the simulation results.

Action 4: Give more checkpoints during the semester for students to work on their projects. This avoids students from turning in work in the last minute rush.

Suggestion: The data collection problem is a common challenge for simulation projects of discrete event systems. It is suggested that industry and academia work together to provide some real problems and real data, similar to IISE/Arena Student Simulation Competition [5], for the Simulation educational community.

3. Two examples of successful student projects

Two examples on successful student projects are provided in this section. One is simulating a service system, and the other is on a manufacturing system.

Project 1: Uber vs traditional taxi-comparison in waiting time and availability

This simulation study applied Arena® to simulate traditional cab service and Uber services with objectives of comparing waiting times and ride availability in different times of a day for a ride from Downtown Richmond Marriot to Richmond International Airport [6]. Students delivered this project in the Fall 2015. Data on time and percentage of availability was collected by calling the cab company and setting an Uber App to order a ride every 15 minutes from 8:00 AM to midnight. The collected time data includes two parts: a) time for the ride to show up to pick up the passenger from the moment that the passenger contacts taxi services or connects to the Uber App; and b) from then to the Richmond International Airport. The example of collected data and analysis was illustrated as below Table 2. The Arena® models for taxi and Uber services are illustrated in Figures 3 and 4. Finally, the student also compared taxi and Uber services in terms of waiting time and availability using "Output Analyzer". It was found that Uber serves customers with a faster service by arriving faster to pick up with -20.6 minutes in mean, which is half of the time it takes to use taxi's services. In terms of availability, Uber rejected customers by 9.66% less than taxi in mean.

Table 2. Data Collection and Analysis [6]

	Distribution	Unit	p-value
Taxi Operator-Book a Ride	POIS(0.59)	min	<0.005
Taxi-Pick up Time	NORM(27.8,11.5)	min	<0.005
Uber App-Set a pick up	29.5+91*BETA(0.48, 0.974)	Sec	<0.005
Uber-Pick Up Time	ERLA(0.435,6)	min	<0.005
Taxi’s Waiting for Passenger	10+EXPO(54.5)	Sec	<0.005
Trip To Airport Time	15.5+LOGN(5.35, 4.26)	min	<0.005

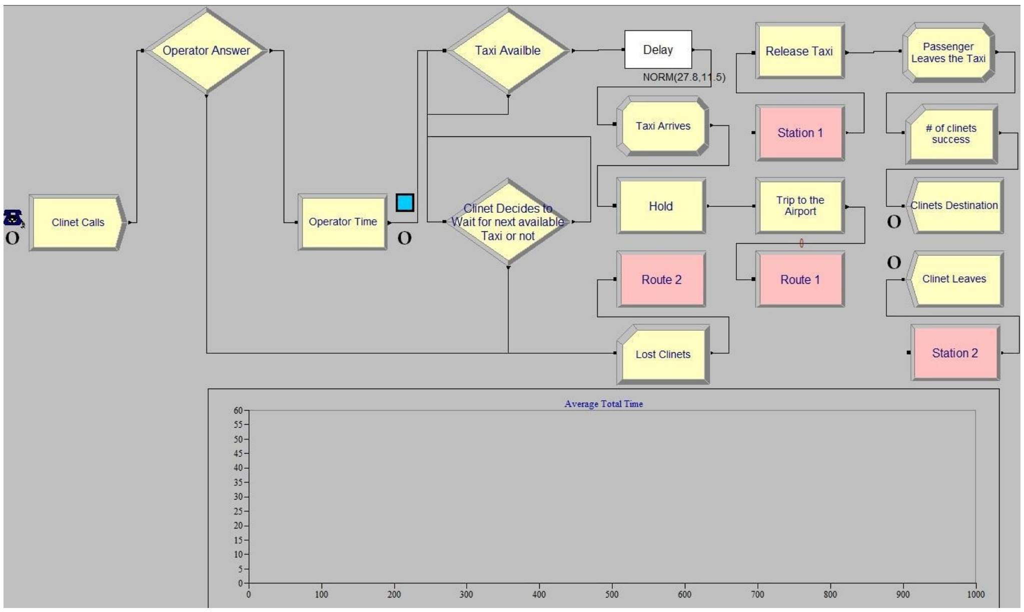

Figure 3. Arena Model on the Traditional Cab Service [6]

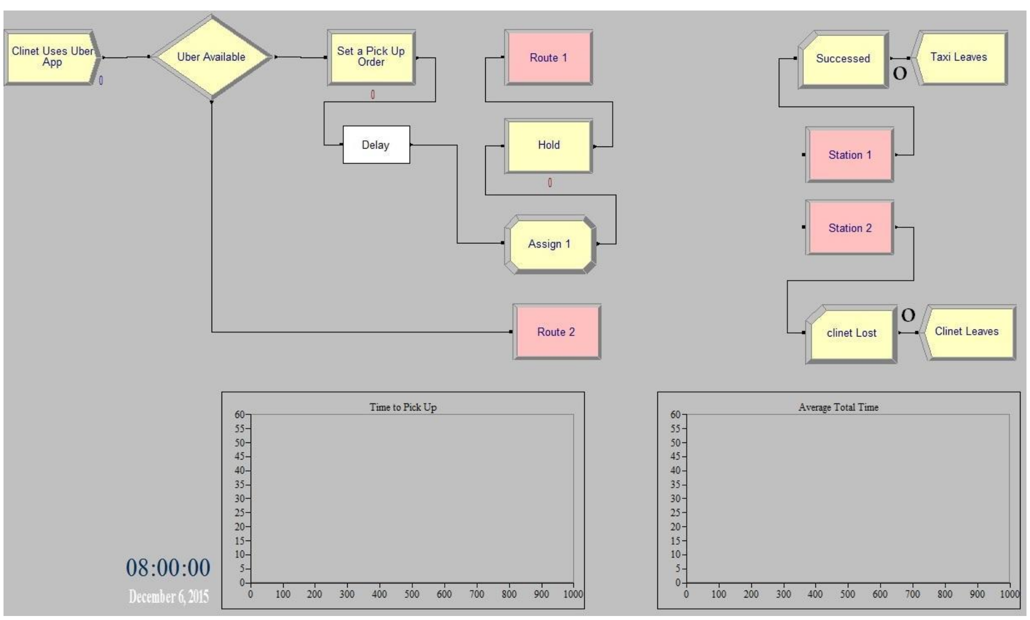

Figure 4. Arena Model on the Uber Service [6]

Project 2: Simulation on a gauge inspection in a bearing company

This project examined the cup inspection process in a bearing manufacturing company [7]. Students delivered this project in the Fall 2019. The operation processes of inspecting cups go through: arrival of cups, washing of cup, flipper, and measurement. The cup inspection machine is new to the company, which can be improved on operation. The project goals to ensure that the inspection process time stays below 40 seconds while increasing total outputs. The project team did thorough data collection and analysis on inter-arrival time of the bearing cups, and process time on each process. Because the process is controlled by programing logic controllers (PLCs), the process times are mostly constant. The inter-arrival time is stochastic, and the collected data on inter-arrival times is as Figure 5. The Arena® model was crafted as Figure 6 with the collected data and processes. The students also identified the bottleneck in the inspection process and proposed a solution to the bottleneck.

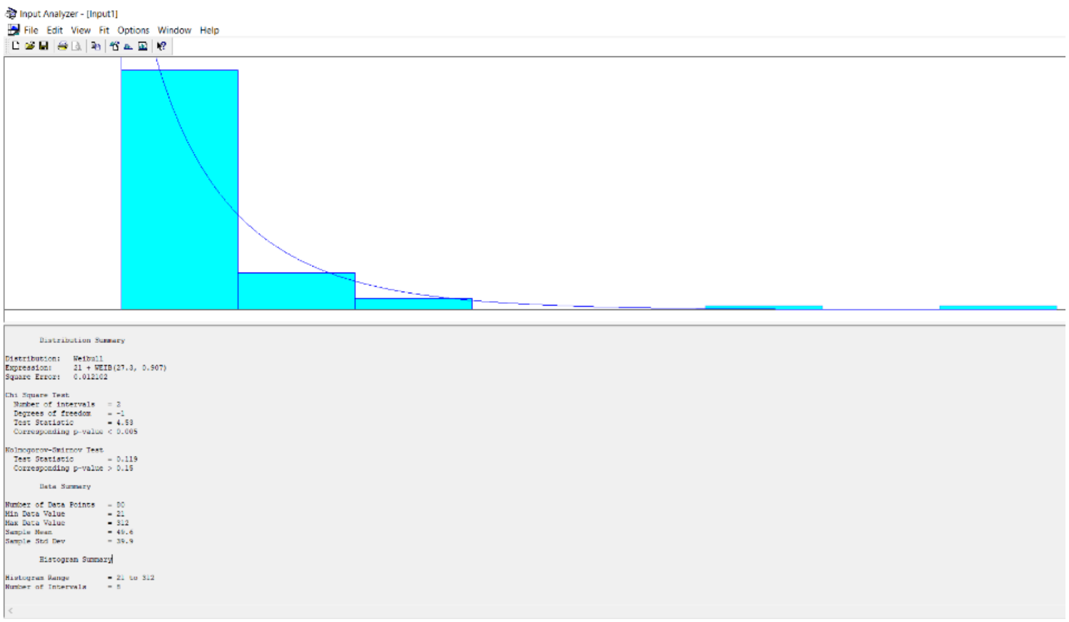

Figure 5. Data Collection in the Project [6]

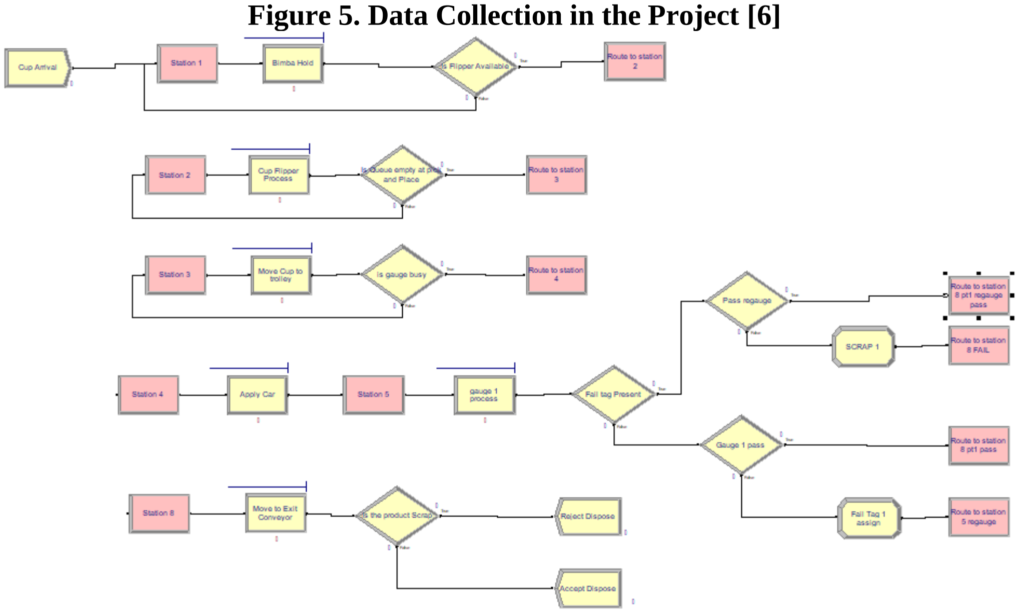

Figure 6. Arena Model of Bearing Cup Inspection Process [6]

4. Common Features of Winning Projects

The aforementioned projects share features enabling their success. First, both problems are real and interesting, with focused but crystal-clear study objectives. Second, students sufficiently collected and analyzed key input data. When data was not available, students also made reasonable assumptions on the inputs. Third, both projects modeled the system with clear process flow and applied animation to help understanding of system operation. The performance measures used in the simulation were appropriate and accurately tracked. Fourth, they statistically analyzed the performance measure using "Output Analyzer" and summarized the findings with tables and/or graphs. They also compared different scenarios on system operations using statistical analysis. Finally, both projects delivered well-written reports.

5. Conclusion

The paper demonstrated using Kaizen process for continuous improvement in Simulation course project. Following the PDCA cycle, it detailed the identification of problems and actions to clear the problems, and check and acknowledge in improving student learning in simulation project. Two student works demonstrated the successful features of simulation projects. The Kaizen process presented here can not only be used for continuous improvement of Simulation course, but also be referred for other engineering course education.

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