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Gokhan Egilmez
University of New Haven, gegilmez@newhaven.edu

Dusan Sormaz
Ohio University

Ridvan Gedik
University of New Haven, rgedik@newhaven.edu

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Dr. Gokhan Egilmez, University of New Haven

Gokhan Egilmez is as assistant professor in the Industrial and Systems Engineering program at University of New Haven. He previously worked as assistant professor of Industrial and Manufacturing Engineering at North Dakota State University and postdoctoral research associate in the department of Civil, Environmental and Construction Engineering at University of Central Florida. Gokhan has Ph.D. in Mechanical and Systems Engineering, M.S. degrees in Industrial & Systems Engineering, and Civil Engineering from Ohio University, and B.S. in Industrial Engineering from Istanbul Technical University, Turkey. His research interests cover a variety of topics that include engineering education, applied optimization and simulation modeling, social, economic and environmental life cycle assessment, data analytics, engineering education, energy and sustainability, input-output analysis, transportation sustainability and safety. Gokhan has over 50 peer-reviewed publications in prestigious academic journals, books, and conference proceedings related to sustainable development, life cycle assessment, manufacturing system design and control, supply chain management, transportation safety assessment, and predictive modeling & machine learning. For more information, please visit his personal blog at https://gokhanegilmez.wordpress.com/

Dr. Dusan Sormaz, Ohio University

Dr. Dusan N. Sormaz is a Professor of Industrial and Systems Engineering at Ohio University, Athens, USA. Dr. Dusan N. Sormaz's principal research interests are in Lean manufacturing, Simulation, Additive Manufacturing, Process planning, and application of knowledge-based systems in manufacturing. He teaches Lean manufacturing, Simulation and Computer Integrated Manufacturing courses at Ohio University. His student team recently received the 1st place among 220 teams from 11 countries in the Global simulation competition sponsored by Simio company. He has published his research (over 100 refereed papers) in refereed journals, the four book chapters and at international conferences. He serves as a reviewer for several international journals, and he co-edited proceedings of Group Technology/ Cellular Manufacturing World Symposium 2003.He is the general chair of the Flexible Automation and Intelligent Manufacturing conference FAIM2018 which is being organized by the Russ College in June 2018 in Columbus, OH. Dr. Sormaz received his Ph.D. degree in industrial and systems engineering and MSc. in computer science from the University of Southern California, Los Angeles, CA, and MSc in industrial engineering and BS. in mechanical engineering from University of Novi Sad, Yugoslavia. He is a member of IIE, a senior member of SME, and member of IEEE.

Dr. Ridvan Gedik, University of New Haven

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[1]Gokhan Egilmez, [2]Dusan Sormaz, [3]Ridvan Gedik,

[1]Assistant Professor, Department of Mechanical and Industrial Engineering, University of New Haven, West Haven, CT (Corresponding Author, Email: Gegilmez@newhaven.edu)

[2]Professor, Department of Industrial and Systems Engineering, Ohio University, Athens, OH

[3]Assistant Professor, Department of Mechanical and Industrial Engineering, University of New Haven, West Haven, CT

Abstract

In this study, application of experiential learning into graduate and undergraduate curricula of a industrial system simulation course is presented. Simulation has been among the courses against which students feel uncomfortable or frightened due to heavy software use, prerequisite of probability, and statistics knowledge, and its application requirements. To minimize this fear and improve student's understanding about the subject matters and have them develop ample skills to build complex models, a project-based learning approach is proposed and used in undergraduate and graduate teaching settings. To achieve the project-based learning goals, a 15-week curriculum is designed to have a balanced lecture and lab sessions, which are specifically designed to address the needs of the term project as the semester continues. In the term project, groups of 2-3 students were asked to form a group, where each group was expected to work on a real system to 1) understand, conceptualize, and model the existing system as a mental, then software-model; 2) validate the existing system model statistically; 3) identify areas for improvement (in addition to the ones given by the supervisor); 4) complete the project with testing out system improvement scenarios and conducting cost/benefit analysis. The effectiveness of project-based learning is surveyed and studied based on the course learning outcomes. The results indicated that the proposed project-based learning approach was found to be effective in students' learning experience and critically supportive on reaching the learning outcomes, and it was found that students' learning and skills of simulation modeling and application are improved regardless of their grade.

Introduction

Problem-based (PrBL) and project-based (PjBL) learning methods are still fundamental to engineering education to cope with the challenges that the new industry trends, advanced technology, and complex business organizations bring into real life as the time goes. They also keep the instructors up-to-date with the challenge of creating and defining new problems or projects, which help the engineering education continuously update itself with respect to the upcoming positive trends and crises in business organizations. Besides, both PrBL and PjBL approaches help students gain ability to understand, define, and reflect a problem with professional engineering language and terms, which is one of the crucial expectations of business organizations that hire engineers. In the following sections, both PrBL and PjBL are explained in detail. Even though the literature uses PBL for both Project-based and problem-based learning; PrBL and PjBL notation is preferred since both will be discussed.

Problem-based learning (PrBL)

PrBL was first used at McMaster University in Canada for the study of medicine in 1969 [1]. It has been widely-proven across various engineering disciplines that PrBL is a very effective learning approach for students since they learn better when they work on practical examples [2]; [3]; [4]. In a PrBL setting, a problem is introduced and solved first, then the generalizing concept is provided. Gosavi and Fraser (2013) provided an excellent application of PrBL in Statistics course that focuses on teaching mean and standard deviation. PrBL has critical advantages that deductive teaching may not directly and effectively provide considering the attention span of students, the need of industry to focus on the problem and result rather than the method. Due to these advantages and PrBL being an experiment-based method [5], learning could be reinforced with different examples prior to providing the theoretical understanding or having a group of students work on the task before the instructor solves the problem and provides the foundational theory behind it. In addition, Gosavie and Fraser listed the other advantages as PrBL is based on inquiry, which could be extended with open-ended problems; ability to retain the knowledge longer period of time and convey it to other problem settings; increased curiosity towards learning; gaining more domain knowledge; and ability to think simultaneously rather than sequentially [2]. Even though termed differently, both PrBL and PjBL require a proactive effort from students.

Project-based learning (PjBL)

Project is termed as "project – "a temporary endeavor undertaken to create a unique product, service, or result."[6]. Projects typically require an organized set of tasks to accomplish the specific goals, progressively updated details within a defined beginning and ending periods, and a unique combination of stakeholders. In this context, knowledge of project management is generally provided with a required sophomore or junior level course in most undergraduate engineering curriculums. Additionally, graduate level industrial engineering programs sometimes offer such courses as elective course. Projects in business organizations can be short term such as preparing a financial report for a fiscal year which could be finished in a month or less; or long term such as construction projects, which may take months or years to complete. Regardless of how long projects take or the level of complexity projects have, we know that most business organizations today are organized with matrix type organizational structure, which requires a substantial project management knowledge and skills [7]. Project management courses at undergraduate and graduate level classroom settings provide the foundational understanding about how to prepare, plan, execute, monitor and manage projects from a birds-eye viewpoint since these courses are taken by engineering majors with different backgrounds in multiple disciplines. In addition to the topic specific knowledge PjBL also requires skills in managing the projects.

Comparison of PrBL and PjBL

A detailed comparison of both teaching approaches is provided in the literature [1]; [8]. The similarities include: 1) both approaches get the students to work, so both require self-direction and collaboration; 2) both approaches can have multidisciplinary focus. The differences include: 1) PjBL requires more tasks that take longer time compared to PrBL; 2) PjBL focuses on application of knowledge; whereas PrBL focuses on the acquisition of knowledge; 3) PrBL is typically applied

in subject-courses such as math, physics, etc. Table 1 summarizes the details of the differences between the two approaches, which were summarized based on the findings in [1,8].

It can be easily seen that it is more effective to utilize PjBL in higher-level courses in college and graduate school, where students already have the foundational knowledge to accomplish the complex project tasks. We mean successful completion of some prerequisite courses in freshman and sophomore years. This is also indicated by [1]. Both approaches are equally important for cognitive and motivational reasons. However, since PjBL requires application and integration of knowledge; while PrBL focuses on acquisition of knowledge; it is safe to say that PrBL is ideal for freshman and sophomore level engineering courses such as math, physics, etc. while both can be easily used in higher level courses. After this discussion, it is critical to ask, what if two are integrated and used together in a simulation course where graduate students (M.S.) and senior industrial and systems engineering students are enrolled. In this study, we will propose a Project-based learning approach used to teach simulation to group of graduate and undergraduate students, which consists of some of the characteristics of problem-based learning.

Table 1. Comparison of PrBL and PjBL [1][8].

	Project-based Learning	Problem-based Learning
Closeness to professional reality	High	Low
Scope	Large	Small
Activity period	Long (Weeks or full semester)	Class time or a week
Direction	Application of knowledge	Acquisition of knowledge
Time & resource management	Initiated by instructor but have to be managed by student(s)	Instructor
Level of self-direction	High	Medium to high
Level of collaboration and role differentiation	High	Low to medium

Literature on Simulation Education

Simulation has become one of the critical courses in IE curriculum especially after the 90s with the increased computerization and computational power in business organizations and higher education institutions. A wide spectrum of simulation software packages and languages are still in-use at various institutions worldwide. Literature includes applications of Excel/VBA [9]; Arena and PROMODEL [10]; Anylogic [11]; SimVision [12], and many others. The use of simulation in education was found to be mostly (67%) in face-to-face settings [13]. Use of simulation in education has been long time recognized by National Science Foundation in a report published in 2003, which indicates that simulation education is critical for all engineering majors due to its definition, entitled “application of computational models to the study and prediction of physical events in the behavior of engineered systems.”[14].

The Proposed Project-based Learning Approach for Simulation Education

The proposed project-based learning approach focuses on having students create simulation project groups in the beginning of the semester. They are given 2 weeks to form their groups and 4 weeks to identify a real system to work on. It is the students' responsbility to find a service or manfuacturing system to build a simulation model for. Some groups are given manufacgturing system simulation projects by the instructor, however since such a service cannot be provided every semester by the instructor; the responsibility is left to students to identify a system to study, understand how it operates, collect data about its processes, build a simulation model, and share the findings with the class audience.

Following is a list of real systems that students have worked on building a simulation model, test, validate, and perform system perforamne assessment and improvement tasks.

1. Manufacturing shop
2. Gas Station
3. Grocery store
4. Coffee shop
5. Hospital
6. Bank
7. Tire shop
8. Movie theater
9. Warehouse
10. Public transportation
11. Parking lot
12. Inventory management
13. Restaurant
14. Dining hall
15. Call center

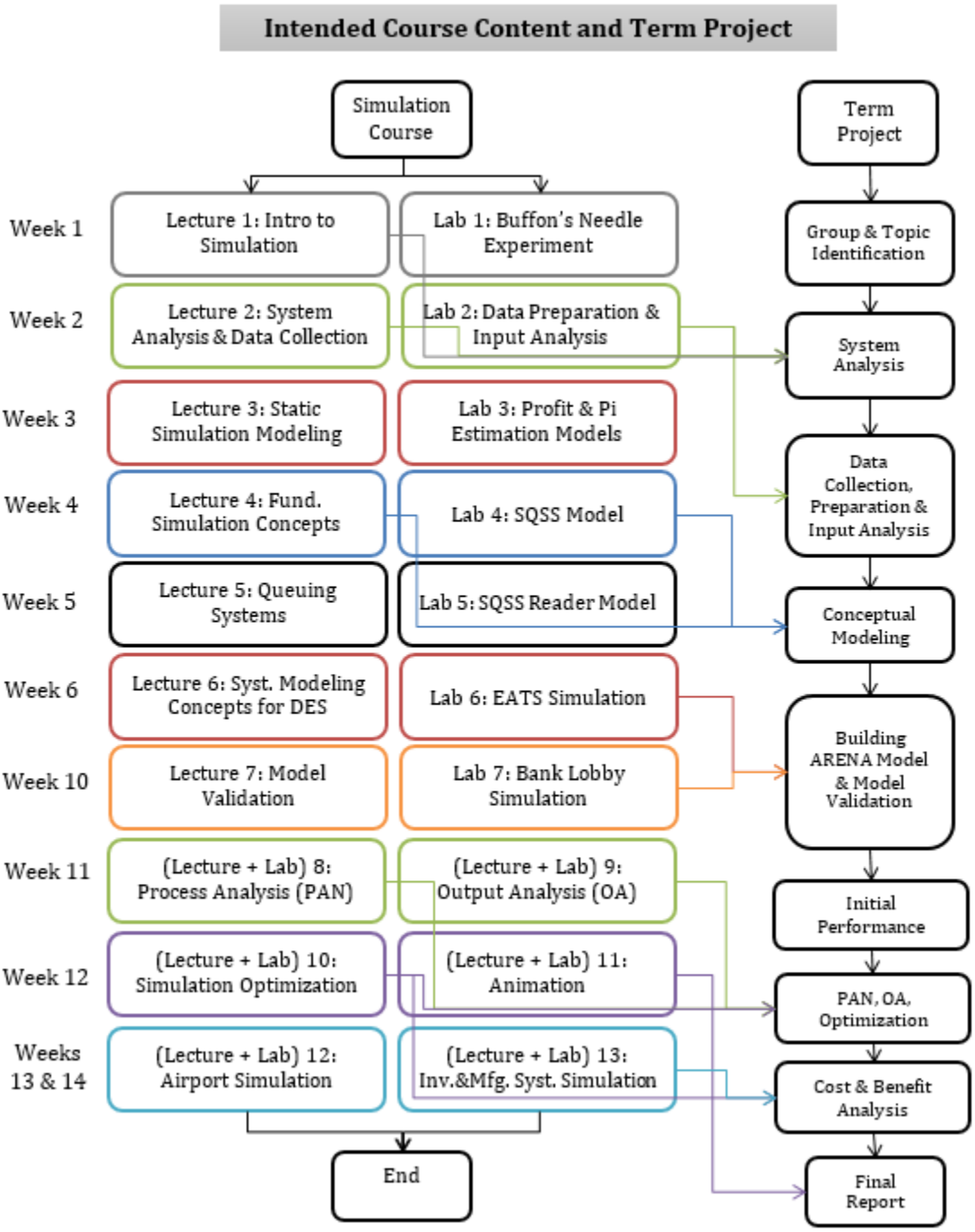
The instructor primarily expects students to gain the knowledge of how to understand and create a process flow map of a system and develop a simulation model for the existing system. Most simulation courses provide students a problem with data, and have them focus on the problems such as longer queues at the cashier, or resource optimization such as optimizing the size of staff at a bank, etc. Even though such methods are quite effective from PrBL, they do not give the essential challenge to students on how to understand, map, and quantify how a system operates from start to end, wheteher it's a manufacturing or service system.

Simulation projects completed in MS Industrial Engineering program at the corresponding author's insitituon are considered as the Cap-stone project requirement to obtain the MS degree, which requires students to take the course typically in their last semester in the program. Same applies to the undergraduate students. The proposed approach has been applied at the corresponding author' institution since Fall 2015 semester. The objective is to have students gain the most benefit from a project-based learning approach by finding a project domain, applying the knowledge gained througut the semester to the specific modules of the simulation project, and writing a professional engineering report in the end with a presentation that is reviewed by class mates. The proposed PrBL is depicted in Figure 1. As shown in Fig. 1, each lecture and lab module is specifically picked to assist with accomplishing a task (or milestone) in the simulation project.

The Simulation course

The course is run with lectures and labs, which pave the way to integrate the acquisitioned knowledge into a project. The course materials include lecture notes and lab session handouts. In most of the lab sessions, a PrBL method is being implemented, which will help the PjBL to be implemented in the semester-long project. In the lectures, student interact with the instructor in a

face-to-face setting, whereas lab sessions are run by teaching assistants and completed during the week, and submitted as lab project assignments. The course material has been primarily developed by the researchers [15]; and used in undergraduate and graduate classroom settings at various uniersities thath the corresponding author has worked [16][1].



[1] Feel free to contact the corresponding author for educational materials.

Figure 1. Flow-chart of Project-based learning approach

The project:

Class project consists of two-phases: 1) system analysis, data collection, and input analysis; 2) Modelling, experimentation, and animation. Hence, the student groups need to deliver two presentations (initial, final) in a semester, along with two project reports (initial, final). The initial report consists of system analysis and data collection, and input analysis phases. It was found very beneficial to have students submit 2 reports and give 2 presentations. On one hand, this approach reduces the available lecture times by one or half week; on the other hand, it forces the students to take more responsibility and put more effort early in the semester and lets them have instructor feedback on their progress early in the semester. The illustration of term project is provided in Fig. 2.

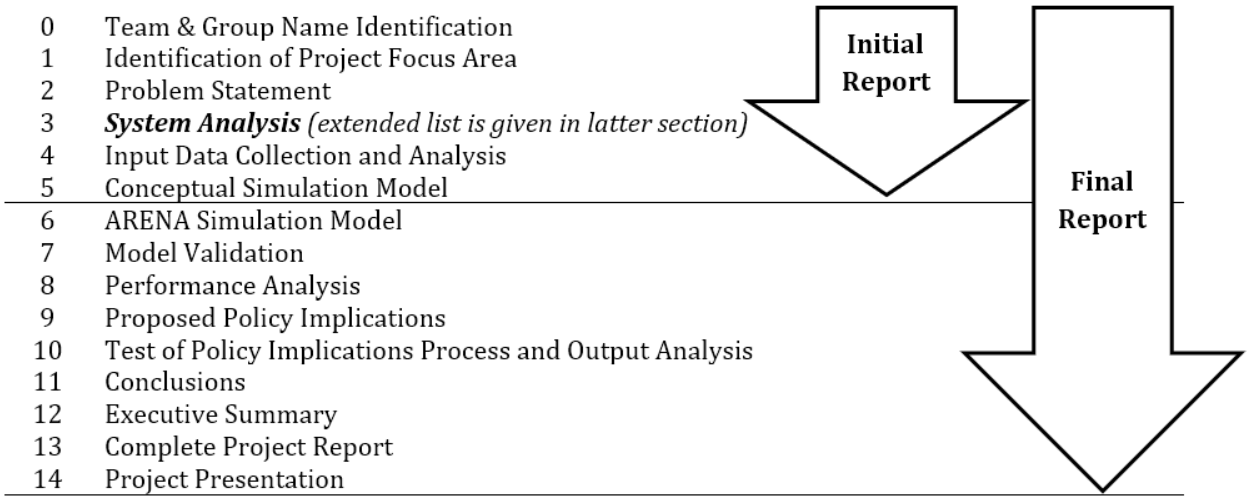


Figure 2. Steps of Term Project

Assessment of Project-based Learning Approach

A survey is developed to assess the students' knowledge acquisition, practical understanding, and skill-development on simulation modeling in general and building a simulation model for a real system in specific. The survey questions consists of three sections, namely: 1) Demographic information, 2) Assessment Learning Experience, and 3) Assessment of specific learning outcomes.

1) Demographic information (First & Last Name, Email, Student ID, Term Course Taken)
2) Assessment of Learning Experience
    a. The simulation project overall positively impacted my practical simulation modeling knowledge and understanding.
    b. The simulation project overall positively impacted my practical simulation modeling skills.

c. The simulation project positively contributed to my engagement with simualtion course.
d. I find the simulation project positively contributing to my career objectives.

3) How effective were the *simulation project* from experiential learning perspective on reaching following specific learning outcomes:
   a. Conducting System Analysis
   b. Identifying and formulating a practical problem from real industry
   c. Collecting, Cleaning, and Analyzing Data from Real Systems
   d. Developing process flow chart
   e. Conceptual system modeling
   f. Performing model validation
   g. Discrete Event Simulation modeling with Arena
   h. Existing system's performance assessment
   i. Scenario Generation and Testing
   j. Developing animation
   k. Project report writing
   l. Delivering professional presentation
   m. Teamwork
   n. Leadership in a group project setting

Additionally, following questions were asked to identify further details on the effectiveness of the learning modules used in class and students nonstructured feedback about the project-based learning experience.

1) What was your favorite learning activity in the Simulation course? (Lectures, labs, Term Project, Homeworks, Quizzes)
2) If you were to improve one aspect of the Simulation Project, what part you would focus on? Any suggestions?

Results

Survey results are collected and analyzed, accordingly. The overall experience with the proposed PjBL approach is assessed with 4 questions, which focuses on the knowledge and understanding, skill development, engagement with the course, the contribution to the career objectives. Results are provded in tabular format in Table 2.The abbreviations used in table are as follows: SA: Strongly Agree, A: Agree, N: Neutral, D: Disagree, and SD: Strongly Disagree.

Table 2. Overall Experience with the *PjBL* Approach

	Category of Assessment	*SA*	*A*	*N*	*D*	*SD*
1	Simulation modeling knowledge and understanding	53%	37%	0%	0%	11%
2	Simulation modeling skills	47%	42%	0%	0%	11%
3	Engagement with the simulation course	58%	26%	5%	0%	11%
4	Positively contributing to my career objectives	58%	32%	0%	0%	11%

The assessment of the overall student experience indicates that in all categories, majority of the students' found the PjBL approach effective in gaining simulation knowledge and understanding, developing skills, increasing the engagement, and well-aligned with their career objectives.
Furthermore, the effectiveness of the project tasks that the students were given to complete are assessed. A specific learning outcome is developed for each task, and assessed in the second part of the survey, with the following Likert scale: EE: Extremely Effective, VE: Very Effective, SE: Somewhat Effective, ME: Minimally effective, and NAAE: Not at all effective. Results of the assessment is provided in Table 3. Results indicate that more than 70% of the students found the proposed PjBL approach effective on reaching the specific learning outcomes.

Table 3. The effectiveness of the proposed PjBL on the specific LOs:

	Activity Learning Outcomes	*EE*	*VE*	*SE*	*ME*	*NAAE*
5	Conducting System Analysis	42%	42%	16%	0%	0%
6	Identifying and formulating a practical problem from real industry	42%	42%	16%	0%	0%
7	Collecting, Cleaning, and Analyzing Data from Real Systems	63%	21%	11%	0%	5%
8	Developing process flow chart	53%	32%	16%	0%	0%
9	Conceptual system modeling	37%	47%	11%	0%	5%
10	Performing model validation	47%	21%	26%	0%	5%
11	Discrete Event Simulation modeling with ARENA	47%	37%	11%	5%	0%
12	Existing system's performance assessment	58%	26%	16%	0%	0%
13	Scenario Generation and Testing	42%	42%	11%	0%	5%
14	Developing animation	32%	42%	26%	0%	0%
15	Project report writing	37%	37%	21%	5%	0%
16	Delivering professional presentation	53%	37%	5%	0%	5%
17	Contributing to teamwork	53%	26%	16%	5%	0%
18	Demonstrating leadership in a group project setting	63%	26%	5%	0%	5%

In the final part of the survey, students were asked about their favorite learning activity (See Table 4). Findings indicate that lab sessions was found to be the most favorite activity that students enjoyed working on. The proposed PjBL approach was predominantly targeting students reach specific LOs by completing the tasks of term project. And, it was found that 37% of the students indicated it as their favorite learning activity. Homework and quizzes were not indicated as favorite activity, which also signals that having courses based solely on HW and quiz type of assessment could make the learning less experiential and less fun.

Table 4. Favorite learning activity

		Lab Sessions	*Term Project*	*Lectures*	*Homework*	*Quizzes*
19	Favorite learning activity	47%	37%	16%	0%	0%

Additionally, to understand if there would be a bias between students' perception of the project-based learning approach and their grades, a correlation analysis is conducted between the weighted total grades of the students and their responses on each of the 18 questions. Results are provided in Fig. 3.

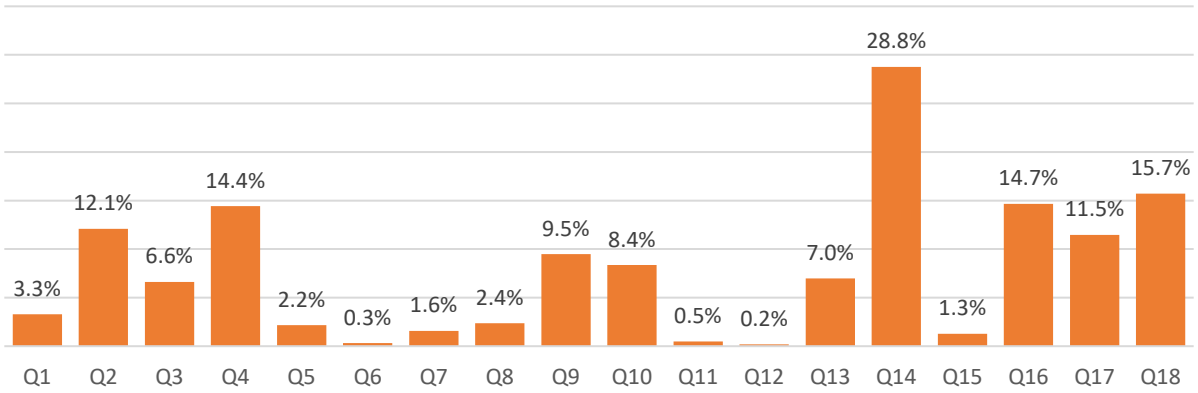


Figure 3. Correlation Analysis

Results of correlation analysis indicate that majority of the questions' evaluations are weakly correlated with the students' grade. The highest correlation was 0.288 between the grades and developing animation. Then, second highest correlation (15.7) was found between grades and the demonstration of the leadership skills in a team. And, the third highest correlation (14.7) was found with the delivery of professional presentation. It can be concluded that there is no significant bias between the students' grades and the evaluations, based on this sample.

Conclusions

In this study, a project-based learning approach is presented. The PjBL approach focuses on having group of students work on a semester long project guided by the instructor to implement discrete event simulation modeling procedures in a real system. The learning module has been in place for three years at the corresponding author's institution. A survey is conducted to investigate the impacts of learning module on the learning effectiveness. It was found that application of project-based learning in Simulation modeling course has a positive impact on learning effectiveness. The course learning outcomes are studied in advance and the term project activity learning outcomes are designed to strongly support the course learning outcomes. The advantages of PjBL approach proposed is that such an experiential education module could provide more practical understanding to students, and ability to connect the theory with the application. Moreover, students take the initiative to learn how to seek information in a real system, define a problem, conduct a system analysis, collect and analyze data, and build a valid simulation model to study. The disadvantages could be as follows. Students are required to find a project site. Some students have complained about having to do the hunting for the project focus, which could be an issue for undergraduate students. However, graduate level course could be more appropriate to implement such strategy, which was the case in this study. The instructor typically spends more time with the students as their specific questions and the points that they were not 100% sure how to proceed are higher in number and deeper in complexity. The best advantage of such structure is that students get to learn from each other's project as each group typically works on a different system. The collaborative learning and engagement significantly increases with the project activities. However, the course needs to be designed around the needs of such project-based approach. Especially, the lab assignments need to be hands-on and practical so that students can have a sound understanding and skill set to deal with *how-to* parts of the simulation software early in the semester.

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