AN ABSTRACT OF THE DISSERTATION OF

Juthamas Choomlucksana for the degree of Doctor of Philosophy in Industrial Engineering presented on August 24, 2012.

Title: A Study of the Impact of Collaborative and Simulation Sessions on Learning Lean Principles and Methods

Abstract approved: ____

Toni L. Doolen

This research is aimed at obtaining a better understanding of the impact of the use of collaborative and simulation sessions for learning lean principles and methods. Study participants were enrolled in a Lean Manufacturing System Engineering (IE436/536) course at Oregon State University or at three other business and engineering universities where lean manufacturing or related courses focusing on lean principles and methods were taught, including Oakland University's Pawley Lean Institute, University of Pittsburgh, and Worcester Polytechnic Institute.

Lean principles and methods have been documented as an effective improvement methodology and have been applied by many organizations globally since the late 1970s. With the widespread application and potential benefit of lean principles and methods, several professional centers, engineering schools, and some business schools, have taught lean principles and methods in order to educate and train learners in lean knowledge and skills before and/or after entering the workplace. Non-traditional teaching methods e.g., collaborative learning activities and simulation

activities aimed at improving training and teaching have been widely used and have been shown to be successful in some studies (e.g., Verma, 2003; Armstrong, 2003; Nikendei, 2007). Little research, however, has focused on how these non-traditional teaching methods might affect learner perceptions e.g., self-efficacy beliefs and attitudes. The relationship between learning and learner perceptions related to the learning of lean principles and methods when using non-traditional teaching methods is also not well understood.

The purpose of this research study was three fold: first, to examine the impact of lean collaborative and simulation sessions on lean learning, self-efficacy beliefs, and attitudes; second, to determine whether or not learner background knowledge had an impact on lean learning, self-efficacy beliefs, or attitudes; and, finally, to explore the relationships between lean learning, self-efficacy beliefs, and attitudes. In the first study, data were collected from students who took IE436/536 Lean Manufacturing Systems Engineering at Oregon State University during the Fall term of 2010 or the Fall term of 2011. In the second study, data were collected from students who enrolled in three other engineering or business schools where lean manufacturing systems or related courses that included content involving lean principles and methods were taught using collaborative and simulation sessions. Data from the first study were used to examine the impact of lean collaborative and simulation sessions on learning, self-efficacy beliefs, and attitudes; data from the second study were used to examine on self-efficacy beliefs and attitudes.

Results from the first study point out the importance of the use of collaborative sessions on learning for both lean methods studied (Jidoka and pull); whereas, the use of simulation, following collaborative sessions, provided benefits only to those students learning Jidoka methods. The research revealed that the content plays a role in the effect of the use of collaborative and/or simulation sessions. Overall, analysis of individual self-efficacy beliefs revealed no significant self-efficacy differences after participants engaged in simulation sessions. The results did indicate that there were significant differences in intrinsic goal motivation after participating in simulation sessions. The level of background knowledge demonstrated a mixed effect on learning and on attitudes. The findings showed a significant difference in learning pull only for some students. The level of background knowledge did impact learner intrinsic goal motivation, but did not impact other attitudes. In addition, the results indicated that the type of session and background knowledge impacted learning; whereas, only self-efficacy beliefs was shown to impact learner attitudes.

In the second study, the overall research findings show that significant differences in learner extrinsic goal motivation resulted from the use of collaborative and simulation sessions. The findings revealed that the sequencing of the teaching methods influenced learner attitudes and self-efficacy beliefs. For example, significant differences in learner task value were found only when participants participated in simulation sessions first, followed by collaborative sessions. Similarly, the results showed that participants from universities, in which learners participated in collaborative sessions first, followed by simulation sessions, had higher levels of self-efficacy beliefs when compared with participants from a university in which learners participated in simulation sessions first and then collaborative sessions.

Taken together, these research findings provide evidence that the use of collaborative and simulation session, as supplemental tools for teaching lean principles and methods, is beneficial. Based on these results lean educators should consider the content areas, the sequence of the use of non-traditional teaching methods, and self-efficacy beliefs as important potential factors in teaching and training lean principles and methods.

A Study of the Impact of Collaborative and Simulation Sessions on Learning Lean Principles and Methods

by

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Juthamas Choomlucksana, Author

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A Study of the Impact of Collaborative and Simulation Sessions on Learning Lean Principles and Methods

1. Introduction

The principles and methods of lean manufacturing, or principles and methods for reducing waste, are growing in popularity in both the manufacturing and service sectors. Lean manufacturing, also called lean, plays an important role in helping companies to achieve success, even in difficult economic times. What is lean, and why is lean important? Lean focuses on improving processes by eliminating waste and applying the concept of continuous improvement across organizations. Lean has been described many different ways. Additionally, Womack and Jones (1994) defined lean as a systematic focus on eliminating waste through continuous improvement activities by increasing the speed and flow of materials and information within an organization. The Lean Enterprise Institute (2003) defined lean as "…maximizing customer value while minimizing waste." In order to gain a better understanding of lean, it is necessary first to know that lean aims to eliminate wastes, reduce costs, and increase value for customers, resulting in increased sales, increased productivity, and a competitive advantage. Wastes are non-value-added activities that exist in any manufacturing or business process. Non-value added activities are defined as activities that do not add value to the process, and activities that the customer would be unwilling to pay for (George, 2002). Moreover, wastes can refer to anything that does not add value to the product and/or manufacturing process. Wastes present in manufacturing operations can be classified into the following seven categories:

overproduction, unnecessary transportation, inventory, unnecessary motion, over processing, waiting time and defects. Waste elimination can increase efficiency, creating a competitive advantage and can also help create an environment in which employees can focus on performing value-added tasks.

Throughout the past decade, researchers have observed the benefits of applying lean principles and methods to manufacturing and, more recently, to service organizations. For example, Dickson et al. (2007) used lean methods, including identifying waste through value stream mapping, in an emergency department to improve care delivery and quality. Lean methods were applied by managers and other participants in the emergency department. During a one year period, the number of patient visits increased by over 9%. The research results showed that lean methods helped the emergency department improve its processes and increase patient flows without increasing wait times and while increasing patient satisfaction levels.

Salem and Zimmer (2005) applied lean to reduce processing time and eliminate non-value adding activities in the construction industry with positive results. Value stream mapping helped employees in construction companies visualize waste and eliminate non-value adding activities in three structural steel erection processes. The main purpose of lean methods is to eliminate non-value adding steps from value added activities. Results from studies of lean implementations in organizations indicated that only 11.4% of the total work was value adding. Similarly, in a process piping system after applying value stream mapping, the data showed that only 7.5% of the total work was value adding (Salem & Zimmer, 2005). Research results indicated that lean principles and methods e.g., customer focus, workplace standardization, waste elimination, and continuous improvement significantly added value to the construction industry.

Hines et al. (2008) summarized an example of lean as applied to the new product development process in a UK engineering company called Fixco. Fixco produces connectors used in low-volume and high-value assemblies, for the auto sport, aerospace industry, and other high reliability industries. The new product development processes were designed to increase customer value. Lean efforts resulted in a 50% reduction in lead-time and a 95% on-time delivery rate, increased from a 65% on-time delivery. Lean activities began by applying value stream mapping techniques throughout the production process. A current-state value stream map identified waste and problems within the production process. A heijunka board, a lean tool, was also used in the company production process. The heijunka board was used to give employees real time feedback and to highlight problems such as scheduling bottlenecks. Within one year of the lean implementation, manufacturing lead times for derivatives were reduced from nine weeks to four weeks. Lead times for specials were reduced from sixteen weeks to seven weeks. On-time deliveries were improved by 80%. The research results support the supposition that lean can produce or result in improvements to the new product development process.

In today’s global markets, many organizations are looking for ways to improve quality and productivity, while reducing costs of organizational processes. A number of organizations have found that implementing lean principles and methods results in improvements to production and service process, identifies and eliminates waste, reduces cost, dramatically shortens lead times, and results in a competitive advantage (Salem & Zimmer, 2005; Ray et al., 2006; Hines et al., 2008). The benefits of lean have gained attention from all over the world, and lean is seen as a successful improvement methodology. For example, according to a 2009 poll by Medical Edge, about 79% of medical device design and manufacturing publication readers said that their companies applied lean methods to reduce unnecessary waste in manufacturing processes.

As a result of the widespread application of lean principles and recognition of the benefits of lean, companies today are looking to hire problem solvers, who can help identify and eliminate waste and reduce costs in day-to-day operations. A successful lean transformation relies on the active involvement all organizational members, from operators to plant managers. Although many companies have trained employees in lean, poor training and lack of awareness of lean principles and methods can result in lean transformation failure. A number of on-site training and workshops on lean principles and methods have been held all over the world. Training and workshop fees typically range from $800-$3000 per class day of training, making lean training a potentially significant investment for organizations (Lean Enterprise Institute: http://www.lean.org/Workshops/WorkshopsAndSeminars.cfm; Worcester Polytechnic Institute: http://cpe.wpi.edu/lean.html; Virginia Mason Institute: http://www.virginiamasoninstitute.org/lean-workshops).

Courses focusing on lean principles are extremely valuable in helping to prepare learners to apply lean knowledge in the workplace. Researchers have found that although there are some lean courses available in higher education, learners remain unclear about the lean principles and methods. For example, Taninecz (n.d.) and Fliedner and Mathieson (2007) contend that while lean principles and methods have been taught for more than decade, stand-alone lean course are rare, and the majority of learners leave engineering programs with a minimal understanding of lean. In addition, when lean is taught, lean principles and methods are typically introduced to learners in the higher education classroom through traditional teaching methods (Thomas, 2008). Traditional teaching methods include assigned readings from textbooks, lectures, and/or case studies. The main learning structure in the traditional classroom is lectures. Moreover, traditional classroom environments are generally characterized as teacher-centered, which consist of lecture-style instruction, limited teacher-student and student-student interaction, and minimal engagement in tasks (Boe & Shin, 2005). Although traditional classroom environments are effective in delivering content for most courses, learners of lean principles often have difficulty understanding how to apply lean principles without practice (Balle, 2005).

Moreover, lean principles and methods involve continuous improvement activities. Lean transformation is a long-term process. All members in an organization undergoing a lean transformation must find ways to continuously improve the workplace. In fact, the real production environment has many complexities. These complexities are difficult to convey in traditional teaching methods. Wan et al. (2008)

stated that traditional teaching methods, which include reading, listening to lectures, or watching video clips, might be helpful for learning lean thinking, but learners may obtain a stronger sense and more direct impression of lean principles and methods through hands-on exercises.

Non-traditional teaching methods such as active learning, cooperative learning, collaborative learning, and simulation are used to improve the quality of teaching and learning in the classroom (Harris & Johnson, 2006). Non-traditional teaching methods are different from other activities associated with the traditional teaching methods such as asking questions, getting answers, and listening to lectures. Non-traditional learning activities share common attributes of providing learners a chance to work, typically in groups with other learners, toward a solution and toward gaining knowledge, skill, and experience during classroom time. These types of teaching activities can be used to supplement or replace traditional teaching methods (Rivera, 1996). Classroom activities associated with non-traditional teaching methods allow learners to experience real-world problems, learn to collaborate with team members, and hone problem-solving skills.

Jungst, Lickider, and Wiersema (2003) found that learners learn better through active learning methods when compared to traditional teaching methods. A benefit of active learning, over traditional teaching methods, is that active learning methods provide learners an opportunity to be actively engaged in learning activities. Active learning methods can be defined as “anything that involves students doing things and thinking about the things they are doing” (Bonwell & Eison, 1991, p. 2). Moreover, McManus et al. (2007) stated that learners learn lean methods better by doing, applying lean methods and working as a team to identify problems and finding solutions to simulated problems. Learning lean principles and methods, such as one-piece flow, without hands-on activities and practice, can be difficult, especially if learners do not have a strong industrial background.

"Simulation" or "games" have been used as non-traditional teaching methods for decades. Educators have used simulations and games with learners of all ages to improve learning and training in lean. For example, Elbadawi, McWilliams, and Tettech (2009) developed several hands-on simulation exercises using a "factory" that manufactured paper planes for teaching lean manufacturing techniques. The hands-on paper plane simulation exercises were used to simulate differences between craft production, mass production, and lean production techniques. The simulation exercises allowed learners to work as a team and to use their knowledge of lean manufacturing techniques e.g. collecting the required data and identifying the value added and non-value added activities for each operation towards the manufacture of paper planes. Researchers compared learner knowledge of lean manufacturing principles between learners exposed to a hands-on paper plane simulation exercises and learners exposed to lean principles using only traditional teaching methods. The research results showed that the simulation exercises improved learning, when compared with traditional teaching methods.

TimeWise, the box game, and lean Lego™ simulations and games are other examples of simulations and games currently used to teach lean principles and methods. These simulations and games are used primarily in industrial training classes and workshops. These simulations and games are designed to provide learners the opportunity to act as a production worker in a simulated manufacturing environment. The simulation setting allows learners to use and practice applying lean principles and methods in simulated environments.

Some researchers have reported on the use of other simulations and games in educational settings. For example, Ozelkan and Galambosi (2007) developed the “Lampshade game” for teaching lean manufacturing to both undergraduate and graduate learners. The lampshade game allowed learners to compare the advantages and disadvantages of lean approaches with craft and mass manufacturing approaches. Similarly, Fang et al. (2007) reported on a Lego car simulation. During the simulation, seven to eight learners were divided into two teams to create Lego car production lines in the most profitable way possible. The research results indicated that simulations helped learners learn how to improve or how to make better decisions during the Lego car production process. The application of existing lean simulations in training, business, and education are described in more detail in Chapter 2.

1.1 **Research Motivation**

Today, learners in industrial engineering have opportunities to work in manufacturing as well as service areas (Nambiar & Masel, 2008). The nature of the work of industrial engineers is to ensure that all goods and services are produced and provided at the right time, right cost, and with the right quality (Zandin, 2001).

Economic and financial crises have forced many companies to focus on improving productivity, improving competitive positioning, and reducing total costs through an increased understanding of and delivery of products and services that meet customer needs. Companies need to find ways to ensure survival as well as to provide other advantages that distinguish themselves from competitors.

Lean is one accepted method for helping companies remain competitive where speed, cost, and efficiency are important. Lean allows companies and individuals to identify opportunities for improvement by eliminating non-value added activities and by integrating continuous improvement into operations. Because of the widespread application and potential benefit of lean, there is a need for employees, particularly industrial engineers, to know, to understand, and to be able to implement lean principles and methods in the work environment. Thus, research is needed to explore the effectiveness of using lean collaborative sessions and simulation sessions in higher education. This research will be valuable to both hiring organizations and teaching faculty. The results will help determine how to make lean learning effective, as well as to help prepare learners to apply lean methods in the workplace.

1.2 **Research Focus**

The purpose of this research was to investigate the impact of collaborative and simulation sessions as a support tool for teaching and learning lean principles and methods in the higher education classroom. The ultimate outcome sought from an application perspective was to identify ways to ensure that industrial engineering (IE) graduates have the knowledge, skills, and ability to lead and apply lean principles and methods to any type of environment.

The focus of the research was on classrooms where collaborative and/or simulation sessions were used. The impact of non-traditional teaching methods on teaching and training lean was measured using a variety of outcomes, including learning and attitudes. In addition to examining the impact of non-traditional teaching methods on learning and learner attitudes, the research examined differences in learning and learner attitudes toward collaborative and simulation sessions while taking into account other factors, such as learner self-efficacy beliefs and background knowledge. Although previous studies have shown that using collaborative and simulation sessions, for example, can improve teaching and training, other factors such as self-efficacy beliefs and attitudes have been shown to have positive effects on learner performance in previous studies (Lorsback & Jinks, 1999; Zimmerman & Kitsantas, 2005; Anjum, 2006; Adeyemo, 2007). Moreover, researchers have found background knowledge also has a positive impact on learner achievement (Tsai & Tsai, 2005), as well as on increasing levels of individual self-efficacy beliefs.

1.3 **Research Contribution**

This research aimed to better understand how to educate future engineers about lean principles and methods before entering the workforce. By providing learners with a deep understanding of lean principles and methods in the higher education classroom, companies can potentially save money and time by eliminating the need to invest in lean training for new engineers thus providing companies with employees who can immediately contribute to waste reduction efforts in the organization. Moreover, a clear understanding of principles and methods of lean manufacturing may lead to increased career readiness.

1.4 **Research Model**

The research model developed for the research study is shown in Figures 1 and 2. The independent and dependent variables were identified as a result of a review of related literature found using multiple databases, including Business Source Premier, Institute of Electrical and Electronics Engineering Education, and Education databases. The independent variables included in this research study were the type of session and background knowledge. The type of session included collaborative sessions and simulation sessions. The dependent variables were learning, self-efficacy beliefs, and attitudes.

The two research models (Figure 1 and Figure 2) are based on two groups of research participants. The first group of participants, called group one, was used to explore the impact of the type of session and background knowledge on three areas: learning, self-efficacy beliefs, and attitudes. The second group of participants, called group two, was used to examine the impact of the type of session in two areas: self-efficacy beliefs and attitudes.

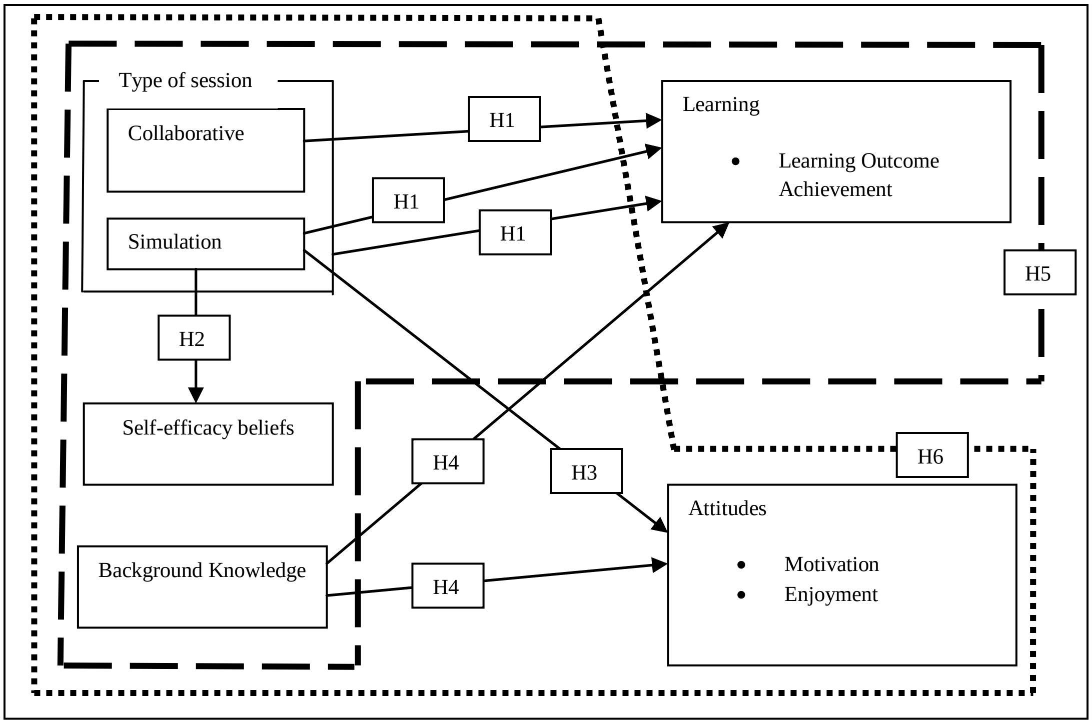

Figure 1: Research model for group one

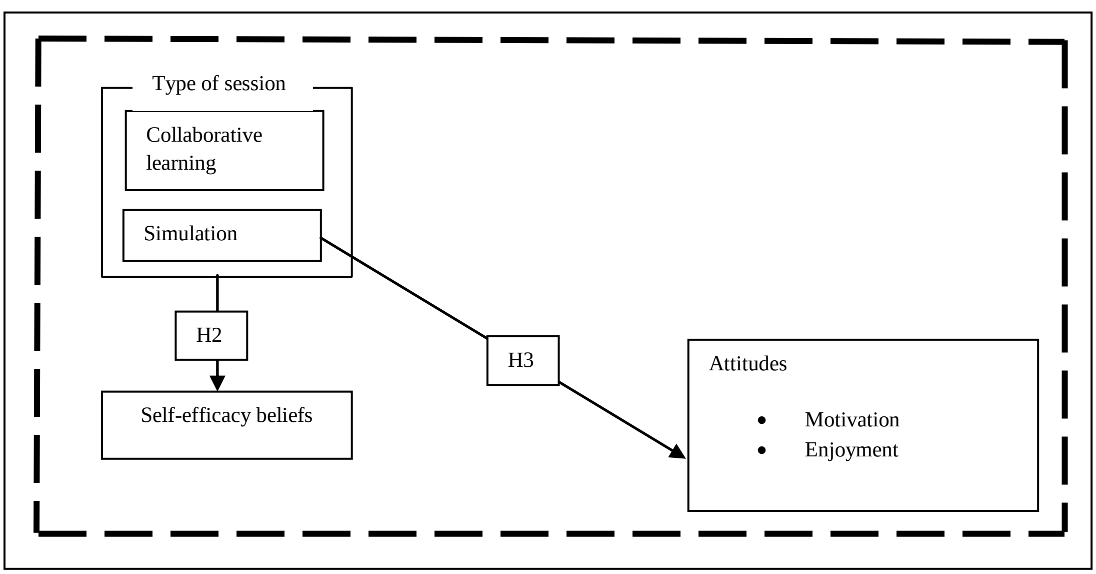

Figure 2: Research model for group two

1.5 **Research Hypotheses**

In order to examine and better understand the effects of the type of session and background knowledge on learning, self-efficacy beliefs, and attitudes, six hypotheses were developed. Table 1 presents a summary of the hypotheses established for this research.

Table 1: Summary of research hypotheses for group one and group two

Hypothesis	Descriptions
Hypothesis 1 (H1a)	Collaborative sessions do not affect learning as measured by learning outcome achievement in group one participants.
Hypothesis 1 (H1b)	Simulation sessions do not affect learning as measured by learning outcome achievement in group one participants.
Hypothesis 1 (H1c)	The type of session does not affect learning as measured by learning outcome achievement in group one participants.
Hypothesis 2 (H2)	Simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy survey scores in group one and group two participants.
Hypothesis 3 (H3)	Simulation sessions do not affect attitudes as measured by learner motivation and enjoyment survey scores in group one and group two participants.
Hypothesis 4 (H4a)	The level of background knowledge does not affect learning as measured by learning outcome achievement in group one participants.
Hypothesis 4 (H4b)	The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores in group one participants.
Hypothesis 5 (H5)	There is no relationship between type of session, self-efficacy beliefs, background knowledge, and learning in group one participants.
Hypothesis 6 (H6)	There is no relationship between type of session, self-efficacy beliefs, background knowledge, and attitudes in group one participants.

Survey instruments were developed to test the research hypotheses. Survey instruments were used to measure participant learning, self-efficacy beliefs, attitudes, and background knowledge.

1.6 **Definition of Terms**

Based on existing studies from related areas, the research variables and other terms critical to this research study were defined and are summarized in Table 2 and Table 3, respectively.

Table 2: Research variable definitions

Variable	Definition
Type of session	The type of session consisted of collaborative and simulation sessions.
Learning	Learning was defined as learner achievements in terms of the knowledge, skill, and ability that a learner demonstrated as a result of what they learned in a particular type of session.
Self-efficacy beliefs	Self-efficacy beliefs were defined as the level of confidence individuals had in their own capability to apply their knowledge and skill for specific tasks in three areas: 1) In their ability to answer lean questions and solve problems related to the examples provided. 2) In their ability to teach lean subject content to peers. 3) In their ability to apply what they learned to real-world problem situations.
Attitudes	Attitude was defined as learner motivation and enjoyment. Learner motivation was defined as intrinsic goal orientation, extrinsic goal orientation, and task value. Enjoyment was defined as the degree of positive feelings resulting from an experience.
Background knowledge	Background knowledge was defined as all information and content knowledge that individual learners had at the time that a survey/test was conducted.

Table 3: Definitions of related terms

Term	Description
Traditional teaching methods	Traditional teaching methods are characterized by teacher-centered learning environments and typically entail lecture notes, PowerPoint presentations, textbooks readings, and case studies. Generally, lecture sessions consist of an instructor using text-based materials to deliver content orally to learners.
Collaborative sessions	Collaborative sessions consist of both lectures and some type of in-class activity. Collaborative sessions require learners to work in teams during class time to achieve a shared learning goal (Barkely et al., 2005).
Simulations	Simulations were defined as live simulations. Live simulations attempt to mimic or stimulate real-life situations or activities. Simulations, when used for teaching and/or training, give learners opportunities to participate in activities that are close to real-life experiences.
Training classes and workshops	Training classes and workshops occur in varying amounts of time, for example, one hour, one day, or for an entire week. The objective of training classes and workshops is to provide participants with specific knowledge and/or to develop specific skills
Defect elimination (Jidoka)	Jidoka is a lean method used to eliminate defects. For example, in manufacturing, Jidoka might be used to stop a line automatically when something goes wrong. Employees then work to fix problems leading to the defects resulting in the production line stoppage.
Pull production (Pull)	Pull production is a lean method implemented to minimize inventory. In pull production systems, manufacturers produce based on actual demand, rather than based on forecasts or schedules developed from forecasts.

1.7 **Research Approach**

All participants included in this research were undergraduate or graduate students seeking a degree in either engineering or business. Participants were divided into two groups, group one and group two. Group one included students who took IE436/536 Lean Manufacturing Systems Engineering at Oregon State University during the Fall term of 2010 or the Fall term of 2011. Approximately 50 students were enrolled in each course. Group two included students enrolled in three other engineering or business schools where a lean manufacturing systems or related courses that included content on lean principles and methods were taught using collaborative and simulation sessions. Participants in group two were selected because the students had direct experience with non-traditional classroom environments using collaborative and/or simulation sessions to learn lean principles.

In this research, a set of survey items were used to collect data and measure four research variables: (1) learning (2) background knowledge, (3) self-efficacy beliefs, and (4) attitudes. Ten surveys were used to measure these four research variables. The ten surveys will be referred to Jidoka1, Jidoka2, Jidoka3, Pull1, Pull2, Pull3, Attitude-Collaborative, Attitude-Simulation, Self-efficacy beliefs/Attitude-Collaborative, and Self-efficacy beliefs/Attitude-Simulation. The first eight surveys were used for participants in group one and the other two surveys were used for participants in group two. Completion of each survey took approximately 10-15 min. The ten surveys included a total of 140 items that were of two types: a set of 60 multiple-choice questions and 80 five-point Likert scale items. The 60 multiple-choice questions were developed to measure the level of individual content knowledge and to assess background knowledge of participants on two lean methods (Jidoka and pull).

A total of 80 five-point Likert scale items were developed to measure participants self-efficacy beliefs and attitudes.

Jidoka1 and Pull1 were used to measure participant background knowledge related to Jidoka and pull methods. Each survey consisted of ten multiple-choice content knowledge questions to which participants responded by selecting one of four possible choices. The total best possible score for each knowledge survey was ten.

Jidoka2 and Pull2 were used to measure participant learning related to Jidoka and pull methods, and to investigate self-efficacy beliefs after participating in collaborative sessions in which these lean methods were covered. Each survey consisted of ten multiple-choice content knowledge questions and six self-efficacy beliefs items. The self-efficacy beliefs items used were adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Printrich et al., 1993). For this research study, self-efficacy beliefs were defined as the level of confidence individual participants had in their own ability to perform a task and/or to apply knowledge and skill based on what they learned from either collaborative or simulation sessions. The self-efficacy beliefs survey items were assessed using a 5-point Likert scale (1= Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree).

Jidoka3 and Pull3 were used to measure participant learning related to Jidoka and pull methods and self-efficacy beliefs after participating in simulation sessions in which these lean methods were covered. Each survey consisted of ten multiple-choice content knowledge questions and six self-efficacy beliefs items.

Attitude-Collaborative and Attitude-Simulation were developed to assess how individuals felt, thought and reacted as a result of participating in collaborative or simulation sessions. Attitude consisted of two areas: motivation and enjoyment. The attitude items used to measure motivation were adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Printrich et al., 1993). Three constructs, including intrinsic goal orientation, extrinsic goal orientation, and task value, were used to measure participant motivation. Enjoyment survey items were developed on the basis of previous research conducted by Berg (2007) and Pekrun et al. (2002).

The Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation surveys were developed to assess participant self-efficacy beliefs and attitudes as a result of participating in collaborative or simulation sessions. The Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation were a modified version of the surveys used to measure participant self-efficacy beliefs and attitudes in group one. The Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation survey items were measured using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). Survey instrument details for each research variable are summarized in Table 4.

Table 4: Summary of research variables, research instruments, participants, and survey administration details

Research Variable	Instrument	Participants	Administration Details
Learning and background knowledge	Three sets of survey questions. The survey questions were used to measure two areas of participant lean content knowledge (Jidoka and pull methods).	Participants who enrolled in IE436/IE536 Lean Manufacturing Systems Engineering at Oregon State University	Administered three times, at the beginning of collaborative sessions; at the end of collaborative sessions; and at the end of simulation sessions.
Self-efficacy beliefs	Two sets of survey items	Participants from both groups (group one and group two) who studied at OSU or other engineering or business universities or colleges.	Administered two times, at the end of collaborative sessions and at the end of simulation sessions.
Attitudes	Two sets of survey items	Participants from both groups (group one and group two) who studied at OSU or other engineering or business universities or colleges.	Administered two times, at the end of collaborative sessions and at the end of simulation sessions.

1.8 **Dissertation Structure**

This dissertation used the manuscript format. As a result, the dissertation is composed of two distinct parts: Part I includes chapters 1, 2, 3, and 8 and Part II includes chapters 4, 5, 6, and 7. Following is a summary of the content for each of these two parts.

Chapter 1 provides an overview of the study, including background, research motivation, research focus, research contribution, research model, hypotheses, and terms, research approach, and research results. Chapter 2 is a review of literature related to lean manufacturing, innovation in education, teaching lean, lean simulation, education outcomes, self-efficacy beliefs, attitudes, and background knowledge. Chapter 3 describes the research methodology, including research questions, research variables, data collection methods, survey item development, tests of validity and reliability, and analysis details. Chapter 8 contains a discussion, conclusions, and summary of potential future work for the overall study.

Chapter 4 and chapter 5 contain modified versions of papers that appeared in the *Proceedings of the 2011 Industrial Engineering and Research Conference*, May 21-25, 2011 Reno, NV and the *Proceedings of the 2012 Industrial Systems Engineering and Research Conference* (ISERC), May 19-23, 2012, Orlando, FL, respectively. Chapter 6 and chapter 7 are the journal manuscripts that have been prepared for submittal to two different journals.

2. Literature Review

This chapter begins with a general overview of lean manufacturing and explores its application in manufacturing and nonmanufacturing organizations. Teaching lean and innovation in education are also described, including a variety of examples of approaches used in classrooms, training sessions, and workshops e.g., collaborative learning and simulations. Detailed information related to educational outcomes is presented. Three types of outcomes, background knowledge, self-efficacy beliefs, and attitudes are described, and a discussion of relevant research studies is included.

2.1 Lean Manufacturing

2.1.1 Lean Manufacturing Overview

In 1990, James Womack, Daniel T. Jones, and Daniel Roos described the success of Japanese car manufacturers in the automobile industry in the book, *The Machine that Changed the World*. This publication popularized the term "lean manufacturing." The actual term "lean manufacturing," also known as "lean" is a strategic improvement methodology that refers to using the fewest resources (e.g., materials, capital investment, inventory, floor space, operating time, and human effort) possible to produce the most output.

The earliest roots of lean manufacturing can be traced to the industrialist Henry Ford who introduced the concepts of assembly lines and mass production in the early

1990s. Ford successfully improved and used the concepts of assembly lines to produce cars in the factories of the Ford Motor Company. Using the concepts of the assembly line and mass production allowed Ford to speed up production and gain a competitive advantage. Soon, Ford's concept was applied to various kinds of products in other industries. Although the ideas of continuous assembly lines and flow systems were used effectively to improve productivity, especially in automotive companies, the drawback of Ford's assembly lines was that manufacturers could not produce a variety of products even when desired by customers. Ford responded to customer requests for color variety on his Model T by saying, "People can have the Model T in any color – so long as it's black." At this particular point in the evolution of manufacturing, assembly lines were designed to produce similar parts or products in large quantities.

In the 1930s, Taichi Ohno and Shingo Shigeo at Toyota Motor Company were interested in Ford's flow production system as Toyota was entering the auto-manufacturing sector. The Japanese developed a new concept in response to a number of Ford's problems (e.g., inability to provide a variety of products), Toyota's limited resources (e.g., raw materials, labor movements, capital investment, and so on), and the smaller market in Japan. The new concept was adjusted based primarily on two new concepts, Jidoka and Just-in-time production. Toyota introduced self-monitored machines, organized machines in process sequence, and pioneered quick setups and changeovers (Womack, 2002) to address these new concepts. Overall, this approach came to be later known as "Just-in-Time system" or the "Toyota Production System." In the 1990s, the approach begun to be popularly known as "lean." Lean allowed

Toyota to gain a competitive advantage by cutting costs, improving production quality, and speeding response times to meet customer demand. The success of Toyota inspired many others, especially U.S. manufacturers, to become more aware of lean manufacturing. Even though lean has been around for decades, lean manufacturing is still considered to be an innovative strategy for improving the operating efficiency of a company or organization.

What is lean manufacturing? Lean manufacturing or lean is an approach that focuses on continuously eliminating waste within work and/or organizational processes and on increasing overall customer value. Lean can be described in many ways. For example, Peterman (2001, p.21) defined lean as "a systematic approach to identifying and eliminating waste (non-value added activities) through continuous improvement by flowing the product at the pull of customer in pursuit of perfection." Lean was described by Shook (1998) as "a philosophy that seeks to shorten the time between the customer order and the shipment to the customer by eliminating waste" (p.4). Lean involves the reduction of waste, also called muda. Muda is the Japanese word for waste. Waste can be defined as non-value adding activities, which is any work or actitivites that do not create value. Since value is defined by customers, non-value added activities can also refer to anything that a customer is unwilling to pay for. Organizations and companies that apply and implement the concepts of lean often work to identify and eliminate waste.

2.1.2 **The Seven Wastes**

Waste or non-value added activities, as defined in the lean vocabulary, can be categorized into seven areas: waste due to overproduction, unnecessary waiting, unnecessary transportation, overprocessing, excess inventory, unnecessary movement, and defects. The term “overproduction” refers to the production of more product than the customer needs. Overproduction results in higher cost in manufacturing and other nonmanufacturing business functions and may lead to excessive inventory, long process set-up, and poor space utilization. Overproduction may also lead to consumption of too many resources, including labor, machines, space, and energy. The term “unnecessary waiting” refers to non-productive human or machine time e.g., waiting for parts, waiting for work, waiting for quality checks, and system downtime. Unnecessary waiting may be caused by inappropriate communication, lack of skill or ineffective production planning in the workplace. Unnecessary waiting can lead to stops in production, bottlenecks, long lead times, and missed delivery dates. The term “unnecessary transportation” refers to excessive moving or handling of materials or parts e.g., transporting work-in-process or transporting parts long distances. Transportation waste may be caused by inappropriate process and value stream flow designs. Transportation waste can lead to increased production time, increased work in progress, and suboptimal use of resources and floor space.

The term “overprocessing” refers to unnecessary or inefficient process steps e.g., poorly selected equipment, duplicate paperwork, and/or unneeded inspections. Overprocessing may be caused by inappropriate standard operating procedures or lack of process understanding. Overprocessing can lead to increases in production time and interuptions in production flow. The term “excess inventory” refers to unused or unnecessary parts, materials, or products e.g., raw materials, work-in-process, finished goods, office supplies or warehouse space. Excess inventory is held to cover up problem areas, often stemming from unreliable raw material suppliers, inaccurate forcasting, and/or unpredictable machine breakdowns or repair times. Excess inventory can lead to increased costs and may create waste in many forms, including tracking, obsolescence, or additional storage facilities.

The term “unnecessary movement” refers to non-productive motion of workers e.g., searching for tools or unnecessary walking. Unneccessary movement may be caused by inadequate worker training, lack of standard operating procedures, and/or poor work and equipment layout. Unnecessay movement can lead to increased production time, costs, and/or energy usage. The term “defects” refers to rework or errors in products or processes e.g., missing parts, scrap, rejects, and recalls. Defects may be caused by inadequate worker training, too many product models, poor work and equipment layout, or poor process documentation. Defects can lead to added costs, inventory problems, delivery failures, and/or decreased customer satisfaction.

Lean implementations often incorporate a number of tools, such as value stream mapping, standardized work, kaizen, kanban, visual control, 5S, and Poka-Yoke. The benefits of these various lean tools have been documented in the literature e.g., Allen et al., 2001; Alvarez et al., 2009; Wojtys et al., 2009. Table 5 maps lean tools and techniques with examples of commom problems faced by organizations working to become lean.

Table 5: Mapping between lean tools and techniques and common problems

Problems	Lean tools and techniques
Over production	Pull system, Kanban systems
Bottlenecks	Takt time calculation, Line Balancing
Defects	Quality at source (Jidoka), 5S, Poka-Yoke
Poor process and information flow e.g. waiting within departments	Value stream mapping, A3 analyses
Lack of communication between departments or within departments	Heijunka board, cross-trained workers
High inventory levels	Pull systems, Kanban systems

Even though lean priciples and methods have been around since the early 1980s, many companies fail in efforts to transform to a lean organization (Santos 1999; Johansen et al., 2004). One of the main factors potentially leading to lean transformation failures may be the lack of clear targets or direction. Many researchers argue that adhering to lean principles can help organizations successfully navigate the transformational process to lean operations (Womack & Jones, 2003; Picchi & Granja, 2004). The five lean principles and the way these principles can be applied to organizations and other industries are described next.

2.1.3 **The Five Lean Principles**

Womack and Jones (2003) defined the main principles of lean as value, value stream, flow, pull and perfection. The first step in the application of lean principles is to define and understand the value in the process from the customer's perspective.

“Value” is that which the customer would knowingly and willingly to pay for. After the initial step of identifying waste, the second step is to identify the value stream for each process in which value is created. This step is used to identify sources of waste and ways to eliminate these wastes. The third step is to define a production process and uses a variety of continous improvement tools and techniques (e.g., Just in time and one-piece flow) to create product or service flows. The fourth step is to define a production process that creates pull, i.e. production only occurs when there is customer demand. Perfection is the final lean principle. Members of the organization seek perfection through continous improvement in both products and processes. The concept behind perfection is to always seek improvement. Even though the application of these five lean principles seems simple and practical, many organizations struggle to implement lean. Even though lean has been widely implemented, only about five percent of organizations or industries have truly implemented lean (Rubrich, 2004). The behavior of employees and the need for organizational change are two of the reasons that many organizations have struggled with lean implementatiojn. The review of literature found that lean implementing requires changed in not only the behavior of employees within the organization (Bakare, 2010), but also often require cultural changes at all levels of an organization. A clear understanding of how lean can change an organization’s culture can aid a successful lean transformation. Research on lean implementation and organizational change are described next.

2.1.4 **Lean Transformation and Organizational Change**

Although lean has been applied widely and most lean concepts, including the five lean principles described by Womack and Jones (1996) have been known for decades, several researchers have found that transforming an organization into a lean organization is not an easy task. Some organizations succeed at implementing lean, but others fail. In particular, researchers have found that many organizations have failed in attempts to create a lean manufacturing system (Smeds, 1994; Nordinm, 2010). The failure rate of lean transformations is estimated to be as high as 70%-98%, based on the Association for Operations Management (APICS), a nonprofit international education organization (Nadler, 2010). Nadler identified several barriers in a lean transformation process, including fear of job loss, fear of failure, lack of big picture understanding, fear of change in the power structure, and conflicting messages. Schlichting (2009) stated seven reasons for lean implementation failures including missing management support, lack of employee involvement, lack of customer focus, operational stability, lack of money, use of wrong tools, and rapid lean conversion. Additionally, according to Cao et al. (2000), four categories of organizational change are required for a successful lean transformation: change in process, change in function, coordination and control, change in values and human behavior, and change in power within the organization. Change in process is change that will help organizations eliminate waste and unnecessary costs through the application of a number of lean tools and multi-skilled workers. All areas of the organization (including engineering, service, and sales) need to understand the customer perspective and how to meet customer needs. Any non value-added activities must be identified and eliminated.

Examples of change in function, coordination, and control are team building, cross-functional work, networking with suppliers and customers, information transparency, participative management, and team based rewards. These changes result in the entire organization working together to achieve organizational goals. Everyone in the organization needs to work together to enable smooth process flows. Changes in values and behaviors are defined as changes that focus on building teams, open communication, information sharing, as well as knowledge sharing. Change in power decentralizes responsibilities and increases the autonomy of the organizational members. For example, engaging all workers in the improvement process would require changes in value and behavior for many organizations. Once the change process has begun, top level managers must transfer power to employees at lower levels, such as shop floor workers, within the organization. Leaders and managers must be willing to authorize others to make decisions. For a successful transformation, everyone in the organization must be aware of and a part of these changes. For example, people may need to be trained how to identify waste, how to select and apply lean tools to eliminate waste, and empowered to improve processes.

Lean is achieved through a cycle of continuous problem solving with a focus on both waste elimination and increasing overall customer value. When successfully applied, lean creates a culture of continous improvement. Santos et al. (2006, p.1) defined continuous improvement as “a management philosophy based on employee’s suggestions." A lean transformation will not occur as a result of applying a variety of lean tools. Instead, a lean transformation requires continuous improvement and commitment from all employees. Long-term commitment to continuous improvement begins at the top level and must be deployed throughout the entire organization. In pursuit of continous improvement, workers within the organization share ideas and find means for improvement. Balle (2005) and Sawhney and Chason (2005) stated that applying lean to an organization requires a culture change in the organization. Since the culture change needed for lean can take months or years, a transformation to lean requires a willingness to change by all members of the organization, including individual workers, as various lean tools and concepts are introduced. Lean is not a single process or single event. Lean is an improvement method that consists of many tools and techniques. By understanding the characteristics and benefits of each lean tool and technique, companies can select the appropriate tool and/or technique to match the organizational need.

2.1.5 **Lean Tools and Techniques**

Lean implementation often relies on a combination of lean tools and techniques. There are many lean tools and techniques, including value stream mapping, Poka-Yoke, pull production systems, 5S Kanbans, Jidoka, one-piece flow, and line balancing. Taken together these lean tools and techniques can lead to improved organizational performance. The benefits of the application of these various lean tools and techniques have been documented in the literature. Applying lean tools and techniques can dramatically reduced waste, while improving efficiency of the production processes. Value stream mapping (VSM) is applied to visually identify the flow of key business processes and to identify improvement activities. For example, Alves et al., (2005) showed that VSM can be effective in identifying inefficient processes for made-to-order products in a job shop environement and in providing directions and opportunities for improvement. Similary, Cookson et al. (2011) demonstrated that VSM can help identify waste and be used to generate ideas for improvement during the initial stages of a lean implementation project within a heathcare setting. In this study, various functions including nursing, medical, managerial and academic staff within an emergency department were exposed to VSM. More than 300 observations of waste were discovered, and suggestions for improvement were identified during observations using VSM.

There are many other examples highlighting the successful application of lean tools. Poka-Yoke is used to either shut down a process or signal an operator to stop the process whan an error is detected. Shimbun (1989, p.xi) stated Poka-Yoke is “a technique for avoiding simple human error at work.” Erlandson (1998) applied Poka-Yoke techniques in a clamp assembly process to improve job opportunities for individuals with cognitive impairements. The research results showed that applying Poka-Yoke generated a productivity increase of 80% and an average percent error decrease from 52% to approxiamtely 1%.

Pull production systems are a common lean tool used to minimize inventory. Manufacturers using pull production produce products based on customer demand rather than based on forecasted demand. One of the goals in lean manufacturing is to produce products or services when an order from a customer is placed. The pull production system has been used to reduce work-in-process inventories and eliminate overproduction. Zheng and Xiaochun (2009) used a computer simulation to model push and pull production systems. The research results showed that a pull production system is able to control the flow of resources in a production process, while reducing the production cost. Zheng and Xiaochun (2009) found that pull production systems create high flexibility in a production process and low inventory. However, pull production systems are not applicable to all organizations. In some situations, push production systems are more successful than pull production systems, particularly when demand variability is high.

5S is a lean technique used to create a visual workplace that is both more efficient and safer. 5S refers to five Japanese words that begin with the letter "s." In a rough English translation, 5S consists of five steps: sort, straighten, shine, standardize, and sustain. Each "S" focuses on organizing and visually controlling the workplace. Sorting is the first step in the 5S process. Sorting aims to remove unneeded or irrelevant tools, parts, and materials from the workplace. Only the necessary tools, parts, and materials remain in the workplace at the end of the sorting process. Straightening or setting in order is the second step. Straightening aims to place everything, including raw materials, work-in-process, tools, and equipement in a specified order and in the right place. This step helps to organize the workplace for maximum efficiency and productivity (by keeping materials as close as possible to where they are being used). All items, parts, and materials should have a place once straightening is finished. Shine is the third step. Shine aims to have all machines, floors, and work spaces clean. The purpose of shine is not only to see that the workplace is clean, but also to anticipate potential equipment or process issues, such as oil leaks from machinery or equipment. Standardization, the fourth step, aims to create policies or procedures to sustain the first three steps of 5S. Creating a schedule as part of a work routine is one way to encorage workers to perform 5S. Sustain is the final step in the 5S process. Sustaining aims to let all workers maintain the improvements made. Understanding the tools and techniques of lean is a necessary factor for organizations that wish to implement lean and to transform to a lean environment. The next section summarizes some examples of lean implementations and illustrates how lean tools and techniques have been applied in organizations.

2.1.6 **Examples of Lean Implementations**

Use of the term “lean” has been documented in the literature over the years. The benefits of a lean transformation have been shown in several industries, both in and out of manufacturing. Organizations have applied lean principles and methods for several reasons. Some have applied lean principles and methods to achieve cost reduction, while others use lean principles and methods to reduce lead times and increase productivity. Lean manufacturing was developed initially for manufacturing organizations. Today, many of the world’s manufacturers as well as service organizations, most recently healthcare organizations, have recognized the value of lean manufacturing and have used lean principles and methods to optimize processes, while reducing operating costs and increasing competitiveness (Lean Enterprise Institute, 2003; Womack et al, 2005).

For example, Machado and Leitner (2010) reviewed 24 case studies of lean transformation in healthcare organizations. All of the cases were analyzed on the organization's basic use of lean tools and the lean transformation processes. The cases were divided into four different categories. The four areas were patient flow, organization, management, and support. Several lean tools such as VSM, conducting time measurements, 5S, standardization, and one piece flow were used in the studied organizations. The research goal was three-fold. The first goal was to identify the most frequently used lean tools in healthcare settings. The second goal was to provide a detailed explanation to help leaders decide which tools can be used effectively. The third goal was to create universal design guidelines and standards that could be used to assist in successful lean transformation in healthcare organization settings.

In another study, Wojtys et al. (2009) showed that lean techniques could be used with considerable success to improve the patient scheduling process in an outpatient sports medicine clinic. VSM was used to evaluate the existing flow of information in the patient scheduling system and to identify and eliminate waste during the patient scheduling process. The results indicated that some patients spent up to 36 days and required up to 21 phone calls to schedule an appointment. Typically only 10% of all steps in a process actually added value. After 14 months of applying lean tools, approximately 76% of patients were scheduled with only one call, averaging 2.5 minutes per call. The study also found an overall positive impact on hospital service quality ratings based on information provided in a self-reported patient satisfaction questionnaire two months after the lean implementation. The study found that VSM was the right tool to eliminate waste while also identifying opportunities to create better flow. The clinic has successfully used VSM to improve the patient scheduling system by eliminating waste in the process, minimizing patient wait times, increasing the speed of room turnover, and improving call center productivity.

Almehareb and Graham-Jones (2010) studied the lean implementation in one aviation company that serves destinations in Asia and Europe. Applying lean tools has helped the company to improve the company performance for both services provided to passengers and the performance of the company. With the creation of an initial and final state VSM, the company was able to reduce travel distance and process time within the system. The company plans to implement lean principles and methods at additional locations in Asia and Europe.

Researchers, Sun and Yanagawa (2006), identified another example of lean implementation benefits. Lean techniques and tools including 5S, one-piece flow, and Poka-Yoke were applied to improve the speed of checking security systems at the College Union at the Oregon Institute of Technology. These tools were presented via student final projects in a lean manufacturing course. Implementation of lean eliminated unnecessary motion, reduced cycle time, created standard work, and most importantly, improved security for the College Union. The results led to a cost reduction of $600 annually through a decrease in the overall operation time for checking and closing the building.

The implementation of lean principles and methods has led to benefits for organizations in both manufacturing and nonmanufacturing organizations. As the potential power of lean transformation and lean benefits have become known, several universities have developed training and workshops on lean principles and methods. Lean has been taught primarily through traditional methods including lectures, Power Point presentations, and case studies. However, since lean is not one simple method or routine process, people in organizations must learn the best way to “see” processes, and, as a result, identify wastes and find ways for improvement. Teaching and training of lean must not only provide a set of principles and concepts, but also provide learners the experience of applying lean knowledge and skills. The use of innovative teaching methods, in general, is described next.

2.2 **Innovation in Education**

Although learning still regularly takes place using traditional teaching methods, many schools and educators have made a variety of attempts to include non-traditional teaching methods in courses with the hope that these teaching methods would improve learning. In traditional teaching methods, lectures have been used as the predominant learning structure; whereby, instructors deliver information to learners who make note of this information. Moreover, traditional teaching methods have a number of specific features, including an instructor who delivers information (content knowledge) to learners, who are required to participate in the classroom at special times. Learners may ask questions or seek help with a topic, and the instructor may answer questions during the class sessions. The instructor might field questions to clarify information that a learner does not understand during the initial delivery. Learner success in this learning system chiefly relies on a learner's ability to absorb information. However, studies found that traditional teaching methods are a learning environment that most individual learners are comfortable with.

O'Malley and McCrew (1999) noted that traditional teaching methods for higher education includes a classroom setting that includes a professor who provides lectures and learners who are listening in the same room and taking notes simultaneously. Similarly, Armstrong (2003) defined the classroom in traditional teaching methods as an environment where a teacher gives lectures while standing at the front of the classroom, writes on the blackboard, and asks learners questions regarding the assigned reading or handouts.

In contrast, a classroom in non-traditional teaching methods reaches beyond a single session by incorporating a variety of techniques that are devloped to encourage learners to learn through problem solving and group discussion. These classroom techniques require that learners exercise cognitive skills, which will lead to intellectual independence. Examples of non-traditional teaching methods, include but are not limited to collaborative learning, active learning, cooperative learning, hands-on exercises, simulations, games, and role-play. The terminologies associated with non-traditional teaching methods are described next.

Some terms, such as collaborative and cooperative learning, have similar meanings. Other terms such as games and simulation are distinct from each other. Collaborative learning, as defined by Harasim (1990), is a group learning that encourages learners to work together on academic tasks, which differs from traditional teaching methods where the instructor is the sole source of knowledge or skills. Collaborative learning encourages learners to share strengths and develop skills in small groups. Seven features of collaborative learning are 1) cooperative task structure 2) shared objective 3) active participation 4) peer interaction 5) shared resources 6) common goals and 7) common reward (Harisim, 1991). Barkley et al. (2005) defined collaborative learning as a classroom session where two or more learners work together toward the achievement of a shared learning goal. Additionally, Chang and Chen (2008) described collaborative learning as interactive activities among learners, an exchange of knowledge, and cooperation in finishing specific tasks. On other hand, the term “active learning” can be defined as “any instructional method that engages learners in the learning process” (Prince, p. 1). Whereas, hands-on exercises are exercise, in which learners directly experienced.

In the field of simulation and games, the difference between games and simulation is that games have a winner and loser, while simulation provides the learner or player with an opportunity to experience a situation that is close to a real-life situation. Simulations are a combination of the features of games (Ruohomaki 1995). Simulations can be classified in different ways. For example, Bredemeier and Greenblat (1981) defined simulations as “a hybrid form, involving the performance activities in simulated contexts (page 14-15)." Raser (1969) defined simulations as a combination of game elements (e.g. human decision makers, roles, and rules) and simulation (e.g. critical features of reality), which allow learners to face real-life experimentation and training. Simulations can include role-playing techniques if a learner or player is expected to think and act as a person in a defined/given role. Many simulations allow learners or players a chance to be involved by playing a role in a simulation. This experience allows the learners or players to apply knowledge in imaginary or real world situations during the simulation runs (Sutcliffe, 2002). Lastly, the term "role-playing" has received considerable attention in many studies, especially in higher education over the past several years. The term "role-playing" and how role-playing can be used with other non-traditional teaching methods are described next.

Role-playing has been described in many studies, but the term "role-playing" appears to also have been in common use within simulation and games for years. According to Van Ments (1989), role-playing is considered to be part of a wider set of techniques collectively known as simulation and gaming. Using role-playing techniques in simulations allows learners to think and act in a variety of roles, including, for example, an employee in simulated environment. Alden (1999) defined role-playing as consisting of three major steps. First, learners are introduced to the purpose of the session. If the style of the role-playing requires learners (also called players) to act in the role, learners are told about the situation and setting for the role-play. Second, the role-play is run. Last, a discussion session is conducted at the conclusion of the role-playing. Brierley et al. (2002) stated that role-playing is a training technique that develops functioning knowledge and includes a combination of propositional knowledge, procedural knowledge, and conditional knowledge. The distinction among propositional knowledge, procedural knowledge, and conditional knowledge is that propositional knowledge refers to knowledge of what things to do. Procedural knowledge is knowledge about how to do things. Conditional knowledge refers to the knowledge of when and why to do things (when and why a procedure, skill, or strategy is used). Armstrong (2003) stated that, "Role play does not usually focus on wining; the emphasis is frequently on how you play the game and reflection on the game" (p. 2). These non-traditional teaching methods have been shown to create successful results in groups of learners of all ages. Examples of non-traditional teaching methods that were used to supplement and improve teaching and training outcomes in many studies are provided next.

Even though traditional teaching methods are well-organized and familiar to most learners, researchers have identified certain benefits of using non-traditional teaching methods over traditional teaching methods. For example, Deutsch (1962) and Johnson and Johnson (1989) proposed that cooperative learning activities provide positive interdependence among learners. The researchers found that cooperative learning activities not only improve learner abilities to reach learning goals, but also help learners understand the importance of team work. Hinde and Kovac (2001) showed that learners received higher scores in classrooms where active learning methods were used than learners in traditional classes. Johnson and Johnson (1989) found cooperative learning improved learning outcome achievement, as well as improved learner motivation, classroom socialization, confidence, and attitudes.

Armstrong (2003) applied role-playing techniques to courses that taught sustainable tourism management. Each student in this study played a true-to-life role in a stakeholder meeting. Amstrong (2003) found that role-playing had a significant impact on student understanding of the course material. The research results also showed that students could empathize with the different stakeholder positions and better understand the obligations after participating in role-playing.

Other researchers have studied the differences between traditional and non-traditional teaching methods on learning. Siberman (1996) found that non-traditional teaching method such as active learning is more effective at embedding concepts and understanding in long-term memory. Similarly, Hake (1988) compared learning outcomes in an introductory physics course between two classroom techniques (lecture based and interactive-engagement methods). Over 6,500 learners enrolled in 62 introductory physics courses participated. Data were collected from high schools, colleges, and universities. During the study, learners were asked to complete surveys using the original Halloun-Hestenes Mechanics Diagnostic test (MD), Force Concept Inventory (FCI), and problem solving mechanical baseline test. Both MD and FCI were used to evaluate student understanding of the basic concepts of mechanics. The researchers found that classrooms using interactive-engagement methods improved problem-solving ability and increased learning of mechanic concepts compared with other techniques.

Recent studies have also shown great success resulting from the use of simulations and/or games in creating significant learning experiences for learners and practitioners. Several simulations and/or games have been used as teaching and training tools for supporting and improving the quality of teaching and learning. Dempsey et al. (1997) conducted a study where the use of simulations and games was observed to improve learning in preschools, K-12 classrooms, universities, military settings, and business domains. Similarly, Akinsola and Animasahun (2007) explored the effect of using simulations for teaching mathematics in secondary schools. The researchers applied two teaching methods to test groups: a regular traditional teaching method and simulations. The results indicated that the simulations improved learner performance and attitudes toward mathematics more than the non-traditional teaching methods.

Even though several non-traditional teaching methods e.g., collaborative learning, cooperative learning, and active learning promote inclusive teaching and training in the classroom, some studies have found that non-traditional teaching methods do not improve learning. For example, Overlock (1994) compared learning in physics classrooms after both traditional and collaborative techniques were applied. Two classrooms of physics at Nova Southeastern University were chosen to participate. One classroom of 18 learners was taught using traditional classroom techniques. The other classroom of 12 learners was taught using collaborative techniques. The final exam was distributed to both groups at the end of the course. Results showed that there were no statistically significant differences in the final exam scores of the two groups. Studying the effects of traditional and non-traditional teaching methods on learner outcomes and achievement can provide direction and guidance in identifying ways to improve teaching and training. Previous research on teaching lean will be discussed next.

2.3 **Teaching Lean**

For many years, lean has received increasing attention from organizations. The financial crisis and global competition have forced companies and industries to look for ways to improve, either by cutting costs or by enhancing the performance of products and services. Companies and industries are forced to do more with fewer resources. The benefits of lean are well-documented and are beginning to be reaped in many different areas and fields.

As a result of this growth, an increasing number of courses, workshops, and training in lean are needed. The benefits of implementing lean have focused attention on teaching and training for learners and practitioners from different specialties and fields. According to online job search postings, there appears to be a need for specialty industrial or manufacturing engineering candidates who are familiar with lean principles and processes (Job Search Engine, 2011). Similarly, Sosnowski (2009), the corporate lean manager of United Solar Ovonic (Uni-Solar) headquartered in Rochester Hills, was a guest speaker at Oakland University's Pawley Lean Institute. Sosnowski mentioned the benefits of lean, "I believe that having lean skills is very valuable in the workplace and at this point is a pretty rare skill set, so it can provide job security." Sosnowski indicated that the application of lean has increased in healthcare, aerospace, construction, medical instruments manufacturing and the military. Moreover, the demand for lean skills is continuously increased according to an annual survey recently published by an executive search firm (IndustryWeek, 2012).

Lean is considered one of the best methods to identify opportunities to create change. Lean courses and lean training workshops may be necessary to help prepare employees and also learners at all levels for the technical and cultural aspects of implementing lean principles and methods. Researchers have found that many organizations either failed or only partially achieved a lean transformation (Liker, 2004; Hamzeh, 2009) because of lack of familiarity with or a misunderstanding of lean (Salem et al., 2005). Pirraglia et al. (2009) investigated lean implementations in the wood industry. The study found that training and educating people on lean principles could allow companies to gain a competitive advantage and achieve substantial product cost reductions.

To date, studies have found that organizations have struggled and have had difficulty with lean implementation and lean transformation (Liker, 2004; Hamzeh, 2009). "70% of lean transformations fail due to the misunderstanding of human interaction and lack of understanding about how people deal with change" (Hall, 2006, p. 474). When first implementing lean, on-site training sessions, and workshops (training outside the work areas) are good options for companies. GrafTech International, a world leader in advanced carbon and graphite materials, opened a lean training center in 2010. The training center has been used to promote and educate employees from the organization around the world on lean principles. The main purpose of the training center is to train all company employees on basic lean concepts (GrafTech, 2010).

The demand for lean workshops and training sessions has been dramatically increasing. Many universities e.g., Oakland University's Pawley Lean Institute and Ohio State University's Fisher College of Business have developed lean courses, workshops, seminars, and certificates that are avaliable to the public. Consulting organizations provide training programs, workshops, and coaching services to help learners or practitioners gain a solid understanding of lean principles and methods. According to training websites, participants report that the training did improve the ability to apply and maintain knowledge and skills learned back in the workplace (TimeWise Management Systems, 2010). Many consulting organization use non-traditional teaching methods e.g., simulations, games, collaborative learning,, and hands-on exercises and/or hands-on activities as part of training sessions with great success. For example, The Lean Enterprise Institute (LEI) was established to facilitate activities related to lean education and training in 1997. The LEI has about 60 university schools e.g., Arizona State University, Indiana State University, University of Dayton, and The University of Warwick (UK) around the world. Lean principles and methods are taught using on-site organizations and off-site workshops. Characteristics of lean training and workshops are described next.

Training and workshops usually vary in length from one day to one month. The main purpose of lean training and workshops is to teach learners or practitioners the concepts of lean and to provide instruction on the use of different lean tools, such as VSM and 5S. With the help of workshops and training sessions, learners or practitioners gain an idea of the steps needed to transition from a traditional manufacturing approach to a lean manufacturing environment. Workshops and training sessions also provide an overview of lean principles for learners and practitioners who might never have heard about lean.

However, external training can be costly for organizations. Training costs vary, but are typically quite significant. For example, one workshop is $800 per individual and covers just two lean methods: 5S and visual workplace (Lean Enterprise Institute, 2011). Training that requires a facilitator to teach people to use VSM costs around $1800 per day (Business Basic, LLC, 2011).

Some universities and colleges have developed courses covering lean principles and methods in order to help graduates gain a competitive advantage in the job market and/or to help graduates become more valuable employees after graduation. In some cases, however, graduates do not truly understand the principles and methods of lean and do not know how to apply lean in the workplace. Simulation is one non-traditional teaching method that has been used as a tool to improve teaching and training in general and that seems to be particularly well-suited the teaching lean principles and methods, especially with learners who do not have manufacturing experience. Some examples of lean simulation that have been developed are described next.

2.4 **Lean Simulations**

Over the past decade, many studies show the trend towards increasing use of lean simulations and/or games as a workplace-training tool or as a support tool for teaching. For example, some universities e.g., Massachusetts Institute of Technology, Ohio University, University of Kentucky, and others have developed and used simulations to teach and train staff about lean principles and methods. Similarly, Verma (2003) reported that at least 17 simulations have been used as a part of lean manufacturing training programs.

Many researchers have found strong evidence that non-traditional teaching methods can be valuable in teaching and training. In response to researchers' successful tests and trials of role-play and simulations and/or games, many educators have developed and applied learning simulation activities to lean courses, including the TimeWise Lean Simulation (Worcester Polytechnic; University of Pittsburgh Northeastern University, 2008), the Lean Enterprise Value Aircraft (McManus et al, 2007), and the Pipe Factory Simulation at University of Dayton (Verma, 2003). These simulations have been implemented to improve learning and to simultaneously minimize the time and effort required for students to learn lean methods. Ozelkan and Galamosi (2007) developed the "Lampshade Game" to teach manufacturing to both undergraduate and graduate students. The researchers discovered that this game helped learners to compare the advantages and disadvantages of craft and mass manufacturing. In another study, Thomas (2008) developed a laboratory simulation exercise for teaching lean techniques using paper airplanes. During the laboratory exercises learners were involved in half-hour sessions. Learners met six times a week over the course. The purpose of the laboratory simulation exercise was to allow learners to work as a team and to encourage learners to use knowledge of lean manufacturing techniques in the manufacture of paper airplanes. Research results have shown that the paper airplane laboratory simulation exercise helped learners learn how to improve and how to make better decisions during the production processes associated with the simulation. Blust and Bates (2004) developed a "Wagons-R-Us" simulation and studied the impact of simulation as a tool for supplementing classroom instruction on lean manufacturing concepts. During simulation sessions, students were asked to assemble wagons using K-NEX© plastic components. Students worked together as a team to help find the best solution to improve the assembly production system. The classroom was divided into three teams. The winning team was the team that produced the highest quality of wagons with lowest amount of waste and manpower. The results from this research showed that simulation provided learners an opportunity to apply knowledge and skills learned in the classroom in a reality-based situation (Blust & Bates, 2004).

Many simulations and/or games have been used to train people (e.g. employees, learners, and practitioners) on lean implementation and to demonstrate the benefits of lean. These simulations and/or games focus on a variety of lean principles and methods including Jidoka, Poka Yoke, pull production, setup reduction, one piece flow, and 5S. Waste identification and elimination is one of the common principles used by all simulations and/or games. Jidoka, 5S, one-piece flow, and pull production are examples of lean methods that have applied in industries with high success. For example, Pirraglia et al. (2009) used survey data to examine companies in the wood industry including manufacturers of engineered wood products, residential furniture, office furniture, doors and windows, in the U.S. where lean has been implemented. The study found that Jidoka has widely been used (about 100%) in the wood industry, especially in companies that have extensively implemented lean principles and methods. Other lean methods such as 5S, one-piece flow, pull production, value stream mapping, and waste identification and elimination have been used for improvement in at least 67 percent of companies surveyed from the wood industry. Table 6 provides some examples of lean simulations and/or games that have been developed for the purpose of teaching and training lean (Garcia, 2007; Hines et al., 2008; Pirraglia et al., 2009).

Table 6: Examples of existing and currently used lean simulations and/or games

Name of simulation/ game	Product	Purpose and process	Developer (sources)
TimeWise Simulation	Clocks	Participants work as a group to assemble two clocks; a blue clock and a black clock. Each participant plays a different role in the clock factory such as assembly operator, production planner, material handler, warehouse clerk, or inspector. Students observe the factory and generate ideas to improve processes and performance.	MEP-MSI (Manufacturing Extension Partnership, Management Services Inc.) (Johnson et al., 2003; Verma, 2003)
Paper Airplane Exercise	Paper airplane	Participants work as a group to build a paper airplane. Four participants are assigned to four workstations in the classroom from raw material inventory to finished goods (airplanes). Other participants observe the session and measure the production time. Each group starts at a different workstation and rotates through all workstations during the classroom time. Three different production systems are used including pull, push, and Kanban system.	Billington (2004)
Lean Lego Simulation	Lego cars	Seven to eight participants are divided into two teams to create a Lego car production line in the most profitable way possible. This simulation consists of two phases of three hours each. Both phases consist of three rounds. Participants are assigned different roles such as supervisor, line worker, material handler, timekeeper, or observer. Five workstations are used for assembling a Lego car with 45 components. A material handler is required to bring parts to each workstation. Each team is allowed to apply the knowledge gained from each round into modifications to the production line.	Fang et al. (2007)

Name of simulation/ game	Product	Purpose and process	Developer (sources)
Box Game Simulation	Box	The simulation requires seven participants to play/run a box manufacturing organization. The purpose of this game is to compare batch-manufacturing techniques or push production systems to a one piece pull manufacturing system. Five workstations are used for assembling a product (Styrofoam box) including delivering a batch of unfolded large and small boxes, putting an elastic band around the large box, putting the small box inside large box and putting a piece of paper on top of the small box and closing the large box with an elastic band around it, opening a large box and checking that all processes completed.	WCM Associates (Verma, 2003)
Lean Enterprise Value (LEV) Simulation	Lego aircraft	Four to six participants at various workstations play different roles in three different areas including manufacturing, supplier network, and product development. Four tables are set up as a workstation for creating Lego aircraft. Tables represent plant A (Wings), Plant B (Tail), Plant C (Fuselage), and Final Assembly in the simulation. Four to five participants are workers and one participant plays the customer. Lego blocks are used to build an aircraft. Two work processes will run during the simulation. First, all necessary parts and assemblies for building Lego aircraft are provided to manufacturing. Second, rework is assigned to manufacturing in order to meet customer specifications.	(McManus et al., 2007)

Name of simulation/ game	Product	Purpose and process	Developer (sources)
Hands-on Lego Model-based Simulation Exercises	Lego motorcycle	Participants work together to build a Lego motorcycle. The number of workstations for the motorcycle assembly line may be created depending on the number of participants. First, participants use batch production processes. Second, the production process changes from a batch production process to continuous flow using a U-shaped layout. Third, participants are required to assemble the Lego motorcycle in a pull production system. At the end of the exercise, participants assemble the Lego motorcycle without any instructions. The exercises provide participants opportunities to apply what they have learned throughout the simulation to the next round.	Nambiar and Masel (2008)
Veebots Simulation	Lego cars	Participants work together in teams to assemble Lego cars. The number of workstations on the car assembly line may be created depending on the number of participants. Participants help each other find ways to improve and reduce processing time to build Lego cars.	University of Kentucky (2004)
5S Simulation	Lego blocks	Six to eight participants from disorganized workplaces work together to apply different elements of 5S in each round. Two 5S techniques including sort and straightening are applied in each round of the game. The game provides participants an understanding the benefits of implementing 5S in organizations.	NIST-MEP (Verma, 2003)

Name of simulation/ game	Product	Purpose and process	Developer (sources)
Plug Factory Simulation	Plug	Six to twelve participants work together on assembling three pin plugs. The simulation provides participants an understanding of lean concepts related to floor layout, push and pull productions systems, one-piece flow, Kanban, line balancing. Participants are required to brainstorm improvements to make between each round.	Lean Games (Sources: http://www.leangames.co.uk/games.php)

The TimeWise Simulation is one simulation used in lean training, workshops and in universities settings. The use of the TimeWise Simulation has also been reported in the literature (Johnson et al., 2003; Verma, 2003; Johnson et al., 2008). According to the TimeWise Institute webpage (http://www.timewiseinstitute.com/) over 320,000 people have been trained in lean using the TimeWise Simulation. The TimeWise Simulation was developed by the Manufacturing Extension Partnership, Management Service, Inc. (MEP-MSI) in 2001. The purpose of using the TimeWise Simulation is to help learners and practitioners to learn and understand why lean principles and methods are important and how the principles and methods work in small-to medium-sized companies. During the TimeWise Simulation, each learner or practitioner is required to read a job description. Each learner or practitioner is assigned a different role such as assembly operator, production planner, material handler, or warehouse clerk, or inspector to assemble two types of clocks in a simulated clock assembly factory. Detailed information about the TimeWise Simulation is included in Chapter 3.

Although lean simulations have had a positive impact on learners and practitioners, the capabilities of these simulations and games have not been fully investigated. Lean trainers and educators need to find ways to assess learner performance and outcomes. The results of such findings may help educators and researchers make more informed decisions for future lean teaching and training. Using and developing tools and methods for assessing outcomes can be beneficial for both providers and receivers. Some examples of learning outcome assessment metrics that have been used to help researchers gain a better understanding of the impact of such approaches are described next.

2.5 Education Outcomes/Learning Outcomes

Education and/or learning outcomes are commonly used to help trainers and instructors measure learner achievement. The definition of "learning outcomes" varies. For example, Donnelly and Fitzmaurice (2005) define a learning outcome as "a statement of what the learner is expected to know, understand and/or be able to do at the end of a period of learning." Donnely and Fitzmaurice also state that learning outcomes represent what the learner has demonstrated or what has been assessed at the end of a course or program of study.

Examples of using simulation and/or games (computer and live simulation) for teaching and training that have been evaluated by measuring learning outcomes do exist (Klassen & Willoughby, 2003). For example, McGaghie et al. (2006) studied the influence of a medical simulation. Thirty-two medical research articles were reviewed. The research results showed that more than 8.1 hours of medical learner practice occur through simulation. The research results reported a positive relationship between medical simulations and learner outcomes. Similarly, Blank (1985) examined the learning outcomes of three different teaching methods (role-playing, case-studies, and computer simulation) in undergraduate courses in agricultural economics. Average exam scores were used to examine the impact of each teaching method in agricultural economic courses during a three year study. The results showed that each method improved learner performance, when used in appropriate situations. Holweg and Bicheno (2002) developed a supply chain simulation called the Lean Leap Logistics Game to demonstrate supply chain dynamics and provide experience with supply chain concepts. Six workstations are used to assemble two products (Red and Blue) including dispatch, final assembly, press shop, blanking operations, service center, and steel milling. DUPLO and LEGO bricks were used as Red or Blue products along the supply chain. The participants represented various levels of management, including directors, planners, schedulers, and graduate-level entry staff. Researchers found that participants were able to understand the supply chain after participating in the Lean Leap Logistics Game.

Similary, Elbadawi et al. (2009) described the use of a paper airplane simulation exercise on learning outcomes. Three different characteristics of craft, mass, and lean production were demonstrated. Twenty-seven participants with no manufacturing experience participated in the study. Pretests and posttests were used to determine participant's learning gains in lean principles and methods (e.g. pull production, kanban, 5S) before and after the paper airplane simulation exercise. The results showed that the simulation exercise had a significant and positive impact on participant knowledge and learning outcomes. Moreover, several studies have explored the use of simulation for lean principles and methods and found that simulation resulted in positive participant attitudes (Fang et al., 2007; McManus et al., 2007; Nambiar & Masel, 2008), but few studies have focused on learning outcomes related to acquired knowledge and understanding of specific lean methods.

Although previous research has found that simulations and/or games positively impact individual learning outcomes (Johnson et al., 2003; Elbadwi et al., 2009), some research has indicated that there is little to no significant relationship between the use of simulations and/or games and individual learning outcomes (Krain & Lantis, 2006). Krain and Lantis studied the impact of a simulation exercise (called the Glogal Problems Summit) on learner performance. Participants were divided into two groups: group one was exposed to material related to nuclear proliferation through a Global Problems Summit. The second group studied the concepts using traditional classroom techniques. A pre-post experimental design was used to evaluate the impact of the two techniques on learning outcomes. The results showed no significant difference between pre and post test results between the two groups.

In addition to looking at skill development and learning related to specific lean principles and methods, three factors e.g., self-efficacy beliefs, attitudes, and background knowledge have also been found to be potentially important factors that influence learner performance and achievement. Previous research on self-efficacy beliefs, attitudes, and background knowledge are discussed next.

2.6 **Self-efficacy Beliefs**

In 1986, Albert Bandura published a book titled, *Social Foundations of Thought and Action: A Social Cognitive Theory*, which first introduced the concept of social cognitive theory (SCT). SCT has been used widely to explain personal behavior. The main concepts of social cognitive theory explain that a person's behavior is always based on the result of interactions among three major factors: behavioral, personal factors and environmental factors. Behavioral factors include self-observation and self-evaluation. Personal factors include mental and emotional aspects of the individual. Examples of personal factors are thoughts, beliefs, biology, and cognition. Environmental factors refer to the social and physical environment. Examples of environmental events are culture, environment (e.g. hot or cold climate), societal factors, politics, and media. Bandura (1997) developed these three factors into a model represented in Figure 3 and called the triadic reciprocal determinism. The model of triadic reciprocal causation was developed to explain the relationships among these three factors (behavioral, personal, and environmental factors).

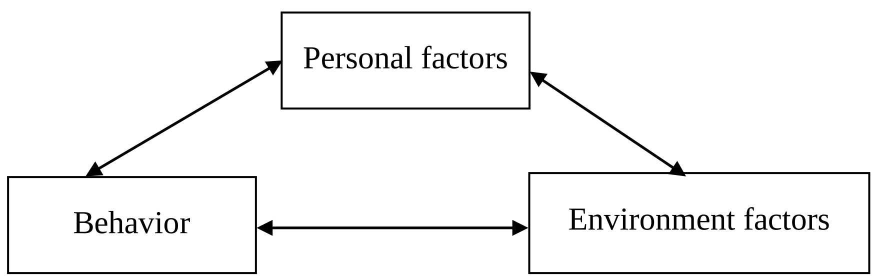

Figure 3: Model of triadic reciprocal causation (Bandura, 1986)

Bandura (1986) developed the concept of self-efficacy beliefs within the structure of the SCT. Self-efficacy is a key mechanism, which contends that human achievement depends on interactions between one’s behaviors, personal factors, and environmental conditions (Bandura, 1986). Bandura proposed the concept of self-efficacy beliefs, which refers to a personal belief that one has the capability to learn or perform a particular behavior to complete a task and achieve a desire outcome.

Bandura (1986) defined self-efficacy beliefs as, “people’s judgments of their capabilities to organize and execute course of action required to attain designated types of performance (p.391).” Self-efficacy reflects people’s belief about whether “they can” or “they cannot” commit to a specific task. People with a high level of self-efficacy not only believe that they can do or complete a task, but they also work harder and show more persistence, leading to greater success. In contrast, people with low levels of self-efficacy believe that they cannot do or complete a task and as a result try to avoid the task. The level of self-efficacy has an impact on the level of effort required and the amount of time required when confronting a task and/or obstacle (Siegle, 2000). Different beliefs related to individual abilities and/or levels of self-efficacy may influence people’s ability to work and to influence each other. Bandura (1977) stated that people learn not only through experiences but also from observing others perform and observing outcomes. People then copy those behaviors. Self-efficacy has been found to enhance an individual’s ability to face difficulties and to sustain efforts to successfully accomplish a task.

Bandura pointed out four experience sources that can affect self-efficacy beliefs. The four main sources are mastery experience, vicarious experience, verbal or social persuasion, and physiological factors. Mastery experience, as the first source, refers to an individual’s previous task experiences and performance. The level of self-efficacy beliefs can decrease or increase depending on individual past experience. For example, feedback on a learner is midterm exam can affect a learner is self-efficacy beliefs related to final grade. Likewise, people who fail to deal with a previous task or cannot complete a task will have lower levels of self-efficacy beliefs, which will affect the learner's ability to succeed at new tasks.

Vicarious experience refers to observing others experiences or performance successes or failures in a similar task or situation. The level of self-efficacy beliefs can decrease or increase depending on observations of others experiences or performance outcomes. For example, one's level of self-efficacy beliefs can increase on seeing others successfully accomplish a task. Bandura (1994) stated "seeing people similar to oneself succeed by sustained effort raises observers' beliefs that they too possess the capabilities to master comparable activities and to succeed." Social persuasion refers to judgments, feedback, and support from others.

The level of self-efficacy beliefs may increase or decrease depending on encouragement and/or discouragement received from other people. For example, people will have a high level of self-efficacy beliefs when receiving encouragement or positive feedback or input from trusted or influential others. On the other hand, negative feedback decreases the level of self-efficacy beliefs.

Finally, physiological reaction refers to physiological factors that affect the level of self-efficacy beliefs. The level of self-efficacy beliefs is based on physiological factors (e.g., moods, emotional, states, physical reactions, and stress situations). For example, people with high stress experience decreased individual levels of self-efficacy beliefs, which in turn can result in task failure. On the other hand, people with no stress may show high-levels of self-efficacy beliefs.

The concepts of self-efficacy beliefs have been shown to influence motivation, task performance, and individual goal setting. One recent study by Lunenburg (2011) showed that high levels of self-efficacy beliefs have strong links to learning, task performance, and individual goal setting. Lunenburg (2011) stated that the reason that self-efficacy beliefs has a significant impact on learning, motivation, and performance is that people try to learn or do a task when people believe or think they can successfully accomplish the task. Further, people with a high level of self-efficacy beliefs tend to learn more from training and also tend to use what they have learned to enhance job performance.

Many previous studies have revealed that self-efficacy beliefs are related to learning and outcomes. For example, Yildirim et al. (n.d.) studied the relationship between learner outcomes and self-efficacy beliefs. Subjects were fifty sophomores and seventeen seniors who were studying industrial engineering at the University of Pittsburgh. Three to four participants were given the model called Model Eliciting Activities (MEA) to solve. Participants were required to solve specific MEA problems and rate how well they believed they did on each question. The goal was to analyze the levels of modeling and problem-solving skills, as well as to measure the individual self-efficacy beliefs of participants. The research results showed that a significant correlation existed between self-efficacy beliefs and performance. Yildirim found that improving self-efficacy beliefs of learners can improve learning outcomes. Similarly, Wang and Wu (2008) examined the role of learner feedback (including learning strategies, providing feedback, performance, and receiving feedback) and self-efficacy beliefs (personal) in a Web-based learning environment. A sample of 76 participants was studied. Homework, questionnaires, and individual feedback on homework were used for the analysis. Learners were required to complete an assignment and questionnaire during the study.

Anonymous peer reviews were automatically received for each learner's homework and sent back to the student through a system, called a research-networked portfolio system. Learners were required to revise homework based on the peer reviews and complete the questionnaires again through the system. The research results supported the idea of Bandura (1997) that self-efficacy beliefs can develop through social persuasion. The results validated the hypothesis that learners with a high level of self-efficacy beliefs will apply more high-level learning strategies, such as elaboration and critical thinking, compared with students who have lower levels of self-efficacy beliefs.

Similarly, in 2009, Isman and Celikli studied the impact of self-efficacy beliefs levels and analyzed learner beliefs towards the use of computer technology. The study included 70 undergraduate students from the Eastern Mediterranean University's Faculty of Education. Approximately 36 participants were from the English Language Teaching Department, and 34 participants were from the Turkish Language Teaching Department. The survey questions were used to collect data to measure individual self-efficacy beliefs levels. Data on past experience, gender, and department were also collected. The researchers found that the number of years participants used the computer had an impact on self-efficacy beliefs. Specifically, the study showed that participants who had experience using a computer for four years or more had higher confidence in computer skills compared with a group of participants who had used the computer for less than four years.

Adeyemo (2007) studied the influence of emotional intelligence on academic self-efficacy beliefs and achievements of university students. A total of 300 participants participated in the study. Participants were asked to complete a questionnaire using the Academic Confidence Scale (ACS) developed by Sander and Sander (2007). The results showed a significant relationship between academic achievement and academic self-efficacy beliefs. Adeyemo found that self-efficacy beliefs were positively significantly related to academic achievement.

Mahyuddin et al. (2006) explored the relationship between self-efficacy beliefs and English language achievement. A total of 1,146 participants from eight secondary schools participated in this study. The participants came from different countries such as Malaysia, China, India, and others. The objectives of this study focused on four areas: 1) the level of self-efficacy beliefs related to knowledge of the English language; 2) the difference in the level of self-efficacy beliefs between males and females; 3) the difference in the level of self-efficacy beliefs between urban and rural schools; 4) the relationship between self-efficacy beliefs and English language achievement. The self-efficacy beliefs scale developed by Bandura (1995) and Kim and Park (1997) were used to measure participant self-efficacy beliefs. The results showed that about 55 percent of participants had high self-efficacy beliefs, and 49 percent had low self-efficacy beliefs related to knowledge of the English language. A total of 44 percent of those people with low self-efficacy belief related to knowledge of the English language believed that English was difficult for them, which resulted in lower motivation to learn. Moreover, researchers found that there was a relationship between self-efficacy beliefs and English learning achievement in English learning. The results showed that participants with higher levels of self-efficacy beliefs showed better performance in the English language compared to those with lower self-efficacy beliefs.

Lorsbach and Jinks (1999) studied the impact of self-efficacy beliefs on learning environments. The researchers concluded that individual self-efficacy beliefs regarding academic performance are an important key to improving learning environments in order to improve learner outcomes. The authors suggested that understanding the concept of academic self-efficacy beliefs aids in understanding what is happening in the classroom and helps educators, instructors, and students improve the learning environment. Zimmerman and Kitsantas (2005) studied whether learner self-efficacy beliefs for learning and perceived responsibility beliefs affects homework practices and grade point average. A total of 179 high school girls participated in the study. The survey was administered during a regular class period at the beginning of the second quarter in the school years. The survey included 86 items in four areas: personal data questions, homework survey, self-efficacy beliefs, and perceived responsibility for learning. Researchers found that homework practice significantly predicted learner self-efficacy beliefs, learning outcomes, and perceptions of responsibility for learning. Learner self-efficacy beliefs and perceptions of responsibility for learning were found to play an important role in both learner homework practice and GPA.

Many researchers have also found that self-efficacy beliefs play an important role in both behavior and performance. There are numeerous self-efficacy beliefs research studies, some examples include computer technology use for self-efficacy beliefs (Isman & Celikli, 2009; Chu et al., 2009) and correlation studies between self-efficacy beliefs and learning achievement (Adeyemo, 2007; Wang & Wu, 2008). To date, researchers suggest that individual self-efficacy beliefs and attitudes are significant, influential factors in academic achievement and work performance. The relationship between attitudes and performance is discussed further next.

2.7 **Attitudes**

Studies of learner attitudes towards simulations are limited. However, previous studies have identified that one of the major uses of simulations is to increase and change the attitudes of participants (Bordon, 1970, p.166) towards a particular topic.

Attitudes are the most important factor that educators and researchers can use to understand and predict people's reactions to objects or changes (Fishbein & Ajzen, 1975). Prokop et al. (2007) showed that understanding learner attitudes could improve learner achievement and increase interest. Prokop et al. studied the impact of learner attitudes in a biology class. The findings of the research showed a relationship between learning and attitudes toward biology. Teacher characteristics have been found to have a significant effect on learner attitudes in the biology class included in the study.

Gardner (1985, p.9) defined an individual's attitude as "an evaluative reaction to some referent, inferred on the basics of the individual's beliefs or opinions about the referent. Two attitudes explored in the literature related to learning are motivation and enjoyment. According to Mullins (1996) motivation is "the driving force within individuals by which they attempt to achieve some goal in order to fulfill some need or expectation." Bomia et al. (1997, p.1) defined motivation as, "a student's willingness, need, desire, and compulsion to participate in, and be successful in, the learning process". Motivation has been found to be positively correlated with learning skills and academic achievement.

Three types of motivation defined in the literature are intrinsic goal orientation, extrinsic goal orientation, and task value. Intrinsic goal orientation refers to the degree to which one perceives his/herself to be participating in a task because the task itself is perceived as challenging and arouses curiosity. Extrinsic goal orientation refers to degree to which one perceives his/herself to be participating in a task because the task itself is connected with a desired external motivator, e.g. a high course grade, a reward, or a course credit. Task value refers to degree to which one perceives his/herself to be participating in a task because the task itself is perceived as important.

Many studies have found significant relationships between learner attitudes and learning. For example, Luckie et al. (2004) argued that a significant and positive improvement in attitudes toward the learning experience might lead to higher achievement. Prokop et al. (2007) studied the relationship between student knowledge and attitudes toward biotechnology. A total of 378 students participated in the study. Students completed two surveys including a biotechnology attitude questionnaire and a biotechnology knowledge questionnaire. The results found a significant positive correlation between attitudes and the level of individual knowledge. Similarly, Gottfried (1980) examined the relationship between academic intrinsic motivation and academic achievement. The research results showed that academic intrinsic motivation was positively related to academic achievement and IQ. The results indicated that a decrease in academic intrinsic motivation might lead to a significant decrease in academic achievement.

Other studies have found a significant relationship between knowledge, attitudes, and achievement (DiEnno & Hilton, 2005; Sorge & Schau, 2002). For example, Depaola and Mclaren (2006) investigated the relationship between learner attitudes and performances in statistics and calculus. The study included 229 participants. Data were collected from individual records, performance on in-class exams, and three surveys. Surveys were used to find out about individual earlier experiences with math, current attitudes toward math and calculus classes. The results found that individuals developed more positive attitudes during the class; however, learners had less positive attitudes towards calculus than statistics. The study results also indicated that learners who earned lower exam scores showed negative attitudes toward statistics and calculus. Depaola and Mclaren (2006) also found that learners who did not have a background in calculus did poorly on the exam and held strong negative attitudes toward calculus.

Similarly, Lin et al. (2001) studied the influence of extrinsic and intrinsic motivation on learning. A total of 650 participants were recruited from four samples of college students in 13 classes, such as biology and psychology at the University of Michigan, Alma College, Washtenaw Community College, Eastern Michigan University, Keimyung University in Korea. The scores of both intrinsic and extrinsic motivation scales were divided into low, medium, and high levels. Items on the Motivated Strategies for Learning Questionnaire (MSLQ) were scored using a five-point Likert scale. The results showed that learners with a high level in intrinsic motivation and a medium level in extrinsic motivation had higher mean course grades than students with either low or high extrinsic motivation. Another study by Eccles et al. (1983) and Eccles (2005) highlighted the importance of learner task value as a positive predictor of intentions and decisions to continuously take mathematics and English classes. Individual enjoyment has also been associated with higher degrees of motivation, learning, and learning outcome achievement.

Moreover, studies have found positive relationships between learner enjoyment and learning outcomes. For example, Blunsdon et al. (2003) found that enjoyment has a positive impact on increasing both learner perceptions and learning outcome achievement. In contrast, Rieber and Nach (2008) studied the impact of game-like activities on adult learning during a computer-based simulation. The research found no correlation between enjoyment and learning outcome achievement. The study revealed that the fun and enjoyment resulting from playing the game disrupted student learning. Although some research showed that enjoyment has been found to be positively related to learner desire to continue learning, other studies have not supported this relationship. As a result there are still many questions to be answered about the effect of learner enjoyment on learning and performance. The role of background knowledge on learning, based on previous research, is discussed next.

2.8 **Background Knowledge**

According to the literature, individual background knowledge may be an important factor influencing learning outcomes and attitudes. Researchers have found that people with varying background knowledge and skills differ significantly in performance and achievement. The term, background knowledge is often used interchangeably with existing content knowledge and prior knowledge. Background knowledge has been defined, for example, by Stevens (1980) as "… what one already knows about a subject…" (p.151). Biemans and Simons (1996) described background knowledge as "… all knowledge learners have when entering a learning environment that is potentially relevant for acquiring new knowledge…" Studies found that background knowledge could have a positive or negative effect on learning (Shapiro, 2004 & Clarke et al., 2005). For example, the findings of Redman (2001) have shown that understanding and recognizing background knowledge helps instructors find ways to more effectively engage students in the class. According to cognitive learning theory (Markus & Zanjonc, 1985), people create new knowledge based on past experiences and/or background knowledge.

Roschelle (1985) reported that most people learn new things by using background knowledge, while few are likely to be successful in learning without linking new information with background knowledge. Dochy et al. (1999) demonstrated that background knowledge played an important role in individual performance. Braasch and Goldman (2010) studied the role of background knowledge on college student learning from analogies in science texts. The results proved that background knowledge positively impacts learning. The findings of the research study showed that learners with more background knowledge in reference to reading the analogy text were better able to understand a conceptual model of weather than those who did not have this knowledge. Yates and Chandler (1994) found that learners who had a wide range of background knowledge and experience before entering a program have been proven to respond quickly and have high levels of confidence in the new skills.

2.9 **Conclusions**

This chapter provided an overview of lean manufacturing, explained how lean can be taught, presented detailed information about innovative approaches in education, and explored the measurment of various educational outcomes. Companies and organizations are always interested in improving products and services in order to achieve goals and to gain a competitive advantage. Since lean is recognized as one of the best improvement methods to help companies and organizations become successful, there appears to be a need for understanding basic lean principles and methods before engaging in lean transformation activities. If correctly implemented, lean can save companies millions of dollars. Although lean manufacturing has gained popularity over the last few decades, studies have shown lean implementation failure rates of over 50% (Kallage, 2006). One of the main reasons for failures in the implementation of lean is the lack of deep understanding of lean and an inability of organizational members to use the appropriate lean principles and methods. By understanding the impact of the use of non-traditional teaching methods on lean learning, this research can provide insight that can be used by instructors to support and motivate learners to better understand more about lean manufacturing. A description of the data collection procedures and the data analysis techniques used to explore the research questions developed for this study will be discussed next.

3. Methodology

This chapter describes the methods and procedures used to generate the data and analyze the data for this research study. It discusses the formation of research questions and provides detailed information about the research variables, procedures, data collection methods, and research instruments. Issues related to survey validity and reliability are also discussed. The chapter concludes with a summary of analysis methods.

3.1 Research Questions

The research questions were developed based on the objective of the research study and a review of related literature. Three research objectives were created. The first objective was to examine and better understand the effects of non-traditional teaching methods (collaborative and simulation sessions) on learning related to lean principles and methods. The second objective was to explore the relationships between learning, background knowledge, self-efficacy beliefs, and learner attitudes towards different types of learning sessions. The third objective was to determine whether or not individual background knowledge has an impact on learning, self-efficacy beliefs, and attitudes. This research was designed to provide insight into whether or not collaborative and simulation sessions positively contributed to learning, self-efficacy beliefs, and/or attitudes. The following nine research questions were developed to address the gaps identified after a review of the literature was completed.

- Do learners demonstrate improved levels of lean knowledge after participating in collaborative sessions?
- Do learners demonstrate improved levels of lean knowledge after participating in simulation sessions?
- Does the type of session affect learner learning?
- Do learner self-efficacy beliefs increase after participating in simulation sessions?
- Do learner attitudes improve after participating in simulation sessions?
- Does the level of background knowledge have an impact on learning?
- Does the level of background knowledge have an impact on learner attitudes?
- Is there a relationship between the type of session, self-efficacy beliefs, background knowledge, and learning?
- Is there a relationship between the type of session, self-efficacy beliefs, background knowledge, and attitudes?

3.2 **Research Variables**

Two independent variables and three dependent variables were defined for the purpose of this research study. The independent variables were type of session and learner background knowledge. The dependent variables were learning, self-efficacy beliefs, and attitudes. See Table 2 for the operational definitions of each of these five variables.

The type of session was classified into two categories. These two categories were collaborative and simulation sessions. Collaborative sessions consisted of lectures and some type of in-class activities. Lectures consisted of one or more instructors presenting a variety of text-based materials using a screen, whiteboard or blackboard. PowerPoint presentations and prepared slides were the primary method of knowledge transmission in lecture sessions. In-class activities incorporated discussion questions, hands-on activities/exercises, and/or in-class exercises in which learners were able to apply acquired knowledge to presented problems within a short period. Moreover, in-class activities consisted of simple activities that could be done in a class period. In collaborative sessions, learners were asked to work together as a group or team before and/or after lectures.

In contrast, simulation sessions incorporated one or more types of simulations used to train and teach lean principles and methods. TimeWise and MouseTrap simulations were the simulations used in the classrooms included in this research study. Simulation sessions were typically conducted in a separately scheduled laboratory session, i.e. not in the classroom session. The length for each simulation session varied.

TimeWise Simulation is usually played in four rounds. The main goal of the TimeWise Simulation is to allow participants to work as a team and to encourage participants to apply lean knowledge to a simulated clock assembly line. Participants experience traditional manufacturing in the first round and learn to apply lean manufacturing principles and methods during the second, third, and fourth rounds. Each round takes approximately 15 minutes to complete and is followed by a group discussion. Each participant may play a different role/task in each run of the simulation. Each participant assumes the role of a person who works in the TimeWise Company. The techniques described here in which participants are assigned to play the role/task, also known as, a role-playing technique. Participants are asked to work in one of four different areas: suppliers (e.g., suppliers, quadrant vendor, hand vendor), manufacturing (e.g., material handler, face assembly, back assembly, clock assembly, hand assembly, kitter, inspection, and rework), support (e.g., supervisor and industrial engineer) or front office (e.g. design engineer, sale representative, and application engineer). A sample of a TimeWise simulation layout is shown in Figure 4.

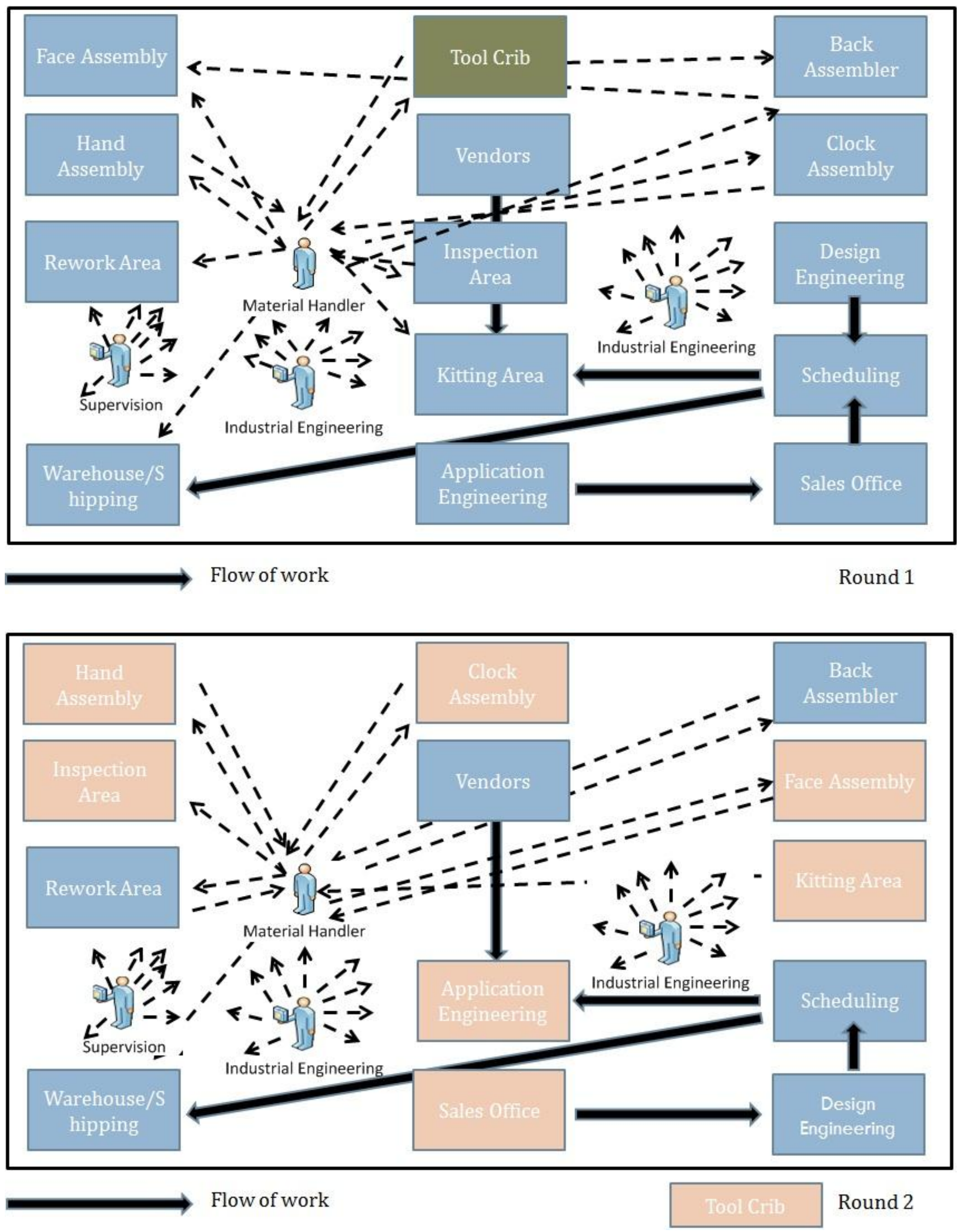

Figure 4: Sample of TimeWise simulation layout (Round 1 and Round 2)

The MouseTrap simulation is aimed to help learners gain a better understanding of lean principles and methods through experimentation. Participants learn lean, while experiencing how lean principles and methods can apply in the Mousetrap simulated environment. The MouseTrap simulation covers the concepts of standardization, Kanban, and plan-do-check-act (PDCA). Pictures from a MouseTrap simulation setup are shown in Figure 5.

Figure 5: Photo from a MouseTrap simulation (Oakland University's Pawley Institute, 2011)

The methods for selecting participants for this research study are discussed next. All participants included in this research study were undergraduate and/or graduate students seeking a degree in either engineering or business. All participants were volunteers. The total number of participants recruited was 155 (73 for participants in group one and 82 participants in group two). All participants were invited to participate in this research study because they were enrolled in a course related to lean manufacturing, and the course used traditional teaching methods (e.g., lectures, class notes, PowerPoint presentations, textbooks, slides) and/or non-traditional teaching methods e.g., collaborative sessions and simulation sessions.

The participants were divided into two groups. Group one included participants who took course called Lean Manufacturing System Engineering (IE436/536) at Oregon State University during the Fall of 2010 or Fall 2011. The majority of the participants from this group were upper division students (juniors and seniors) or graduate students from Industrial, Manufacturing, or Mechanical engineering programs. Group two included participants from three other universities, where a lean manufacturing or related course focusing on lean principles and methods was taught either within an engineering or business program. The data from group two was collected in the 2010 or 2011 calendar years. Three universities participated: Oakland University's Pawley Lean Institute, University of Pittsburgh, and Worcester Polytechnic Institute. Oakland University's Pawley Lean Institute used the MouseTrap simulation; whereas, the remaining two universities used the TimeWise simulation.

3.3 **Data Collection Methods**

All data were collected using survey instruments created for this study. As the research involved human participants, data collection began only after obtaining approval from the Oregon State University Institutional Review Board (IRB). A copy of the IRB approval letter, IRB protocol, and application are included in Appendix A.

Ten surveys were developed and used in the research study. Participants in group one were asked to respond to eight surveys (Jidoka1, Jidoka2, Jidoka3, Pull1, Pull2, Pull3, Attitude-Collaborative, and Attitude-Simulation). Only two surveys (Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation) were administered to participants in group two.

The participants from group one were asked to individually respond to eight different surveys at various times throughout a ten-week term in either Fall 2010 or Fall 2011. The term started in September and ended in December. Surveys were administered to participants before and after both collaborative and simulation sessions. A complete course description of IE436/IE536 and a detailed schedule of survey administration dates are included in Appendix B and Appendix C, respectively.

Jidoka1 and Pull1 each consisted of ten multiple-choice questions designed to measure lean content knowledge. Jidoka2, Jidoka3, Pull2, and Pull3 each consisted of ten multiple-choice content questions and six Likert scale items that were designed to measure learning and self-efficacy beliefs, respectively. Attitude-Collaborative and Attitude-Simulation each consisted of 16 items that were designed to measure learner attitudes. All attitude items used a 5-point Likert response scale (1=Strongly Disagree to 5=Strongly Agree).

For group two, a recruitment letter and/or recruitment email was sent to instructors from a group of targeted schools that were scheduled to offer a course incorporating lean manufacturing principles and methods. Instructors received information explaining the research study including the purpose of the research study and instructions for administering the survey. If the instructors agreed to participate in the research study, student participants were invited to complete two on-line surveys or to fill out two hard copies of the surveys after participating in collaborative or simulation sessions. Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation surveys were developed to assess self-efficacy beliefs and attitudes towards different types of sessions.

Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation were similar to Attitude-Collaborative and Attitude-Simulation surveys, which were administered to participants in group one. However, Self-efficacy beliefs/Attitude-Collaborative and Self-efficacy beliefs/Attitude-Simulation included questions about the background of participants (e.g., school name, class level), a user-provided name to facilitate matching of survey pairs, and self-efficacy items. Each survey contained 22 Likert-scale items. All items used a 5-point Likert response scale (1=Strongly Disagree to 5=Strongly Agree). The development of survey items used to measure learning, self-efficacy beliefs, and attitudes is described next.

3.4 **Learning Survey Item Development**

It has been suggested by Frye (1999) that learning is a measure of “a wide range of student attributes and abilities, both cognitive and affective, which measure how college experiences have supported [student] their development as individuals.”

In this research study, learning was measured using two sets of multiple-choice questions each focused on one of two lean methods. These two methods were Jidoka and pull production. Surveys (Jidoka1, Jidoka2, Jidoka3, Pull1, Pull2, and Pull3) are included in Appendix D. These two lean methods were selected as representative examples of lean techniques and used to assess participant learning from a particular type of session (collaborative session or simulation learning session). The series of content questions were developed by the researcher and reviewed by the course instructor.

Sixty different multiple-choice questions were created to measure content knowledge. Four choices were provided for each question. Each survey contained a total of ten multiple-choice questions. The questions developed were of moderate difficulty and were designed to measure aspects of these methods covered in the course curriculum. Some examples of the questions included on these surveys are provided in Table 7. The full set of questions is provided in Appendix D. Each survey took participants approximately 10-15 minute to complete.

Table 7: Sample of content knowledge multiple choice questions used in the research study

Lean Method	Example Question and Responses
Jidoka	At the end of submitting a purchase order, a customer will be worried if the provided zip code does not match the customer's address. This is an example of which of the following techniques? a. Poka-Yoke. b. Jidoka. c. Andon. d. Muda.
Jidoka	If a plant manager requires that each operation inspects the work of the previous operation. Which of the following may occur? a. Discovers defects. b. Reduces defects. c. Eliminates defects. d. All of the above.
Jidoka	A sensor alarm at the Valley Library gate is an example of which one of the following types of Poka-Yoke? a. Administration Poka-Yoke. b. Warning Poka-Yoke. c. Control Poka-Yoke. d. Setting Poka-Yoke.
Pull production	Which of the following types of Kanban card is used to signal when a machine has broken down? a. A conveyance Kanban. b. A production Kanban. c. A delivery Kanban. d. None of the above.
Pull production	Which one of the following is an example of a push system? a. Snack vending machines. b. Supermarket shelves. c. Laptop customization at Dell. d. None of the above.

Jidoka was first introduced by Shigeo Shingo in early 1900's. Jidoka is a lean method used to prevent and detect production defects. Jidoka is also known as "automation" and "quality at the source." The term "automation" can be described as simulated human intelligence (Khalil, Khan, & Mahmood-Student, 2006) that can eliminate mistakes. The basic idea behind Jidoka is to detect and correct problems. The purpose of Jidoka is to empower workers to take control before a problem occurs or to stop work when a problem or something unexpected occurs (Black, 2008). Andon and Poka-yoke are common tools used in Jidoka to visually control quality and to prevent defects. Many things can go wrong in a manufacturing environment to cause problems (abnormalities and defects). Defects of any kind are wasteful. The methods of Jidoka have helped organizations reduce and eliminate waste, such as over processing, over production and defects. For example, in a study by Berk and Toy (2009) the methods of Jidoka were applied to quality control chart design. Jidoka was used with a conventional control chart as a randomly occurring system stoppage for inspection and repair decision. The authors argued that Jidoka creates an automated system by pointing immediately to the process problem. Jidoka helped reduce company waste by reducing machine setups and downtime costs.

Pull production is sometimes referred to a “just-in-time production” (JIT) in which planning and scheduling of production is based on customer demand. Traditional manufacturing systems typically use push production processes, i.e. the production of products or services is based on forecasts rather than actual demand. A successful implementation of pull production can help companies earn more and waste less through increased workflow speed, reduced inventory levels, reduced lead times, and eliminated scheduling complexities. The topic of pull production was chosen to be included as a representative method because pull production has been shown to positively impact the efficiency of a production system and also because the transformation from a traditional manufacturer to a lean manufacturer often is initiated by the implementation of pull production methods.

Jidoka1 was distributed to participants before any collaborative sessions or simulation sessions on Jidoka were conducted. Jidoka1 was used to measure the background knowledge for participants related to Jidoka. Jidoka2 was distributed to participants after the collaborative session, but before any simulation sessions on Jidoka. Jidoka2 was used to measure content knowledge for participants immediately after participants completed a collaborative session on Jidoka. Jidoka3 was distributed to participants after simulation sessions on Jidoka were conducted. Jidoka3 was used to measure content knowledge for participants immediately after participants completed simulation sessions on Jidoka.

Pull1 was distributed to participants before any collaborative sessions or simulation sessions on pull production were conducted. Pull was used to measure background knowledge for participants related to pull production methods. Pull2 was distributed to participants after the collaborative session, but before any lab simulation sessions on pull production. Pull2 was used to measure content knowledge for participants immediately after participants completed a collaborative session on pull production. Pull3 was distributed to participants after simulation sessions on pull production were conducted. Pull3 was used to measure content knowledge for participants immediately after participants completed simulation sessions on pull production.

3.5 **Self-efficacy Beliefs Survey Item Development**

Self-efficacy beliefs were measured using a modified version of a survey used in previous research. The previously developed survey is called the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al, 1993). Pintrich et al. (1993) developed survey items to evaluate individual participants according to interest, importance, utility and challenge, curiosity and mastery. The MSLQ items have been successfully used by many researchers e.g. Mullen et al., 2006 and Berg, 2007. The internal reliability of MSLQ items have been reported in previous studies, and Cronbach alpha coefficients ranged from 0.62 to 0.93. The self-efficacy beliefs survey used in this research study consisted of six items (see Table 8). The self-efficacy beliefs survey items were modified to specify a type of session: collaborative and simulation sessions. The self-efficacy beliefs survey was distributed to participants at varying times based on the group of participants. For participants in group one, the self-efficacy beliefs survey was distributed four times to assess self-efficacy beliefs related to the two chosen lean methods: Jidoka and pull production. Participants completed the self-efficacy beliefs survey after a collaborative session on Jidoka, after a lab simulation session on Jidoka, after a collaborative session on pull production, and after a lab simulation session on pull production.

For participants in group two, the self-efficacy beliefs survey was completed two times: after a collaborative session or after a simulation session. A 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree) was used for all self-efficacy beliefs survey items.

Table 8: Survey items used to measure self-efficacy beliefs

Survey variables	Item Content
Self-efficacy beliefs	1. As a result of [type of session]*, I believe that I will be able to respond to exam questions on lean manufacturing. 2. The [type of session]* increased my confidence in my own understanding of lean manufacturing principles. 3. I am certain I understand the most difficult principles used in the [type of session] today. 4. As a result of today's [type of session]*, I have no doubt about my capability to do well on lean manufacturing assignments. 5. As a result of today's [type of session]*, I can now explain to my friends what I have learned about lean manufacturing. 6. I am certain I can master the skills being taught in the [type of session]* today.

Note: the phrase, "type of session," was replaced with a particular type learning session e.g.: collaborative or simulation session.

3.6 **Attitude Survey Item Development**

The attitude survey was developed to assess how individuals felt, thought, and reacted, as result of a particular session. Two different attitudes were measured, motivation and enjoyment. Items from the MSLQ used in developing self-efficacy beliefs items were modified to assess motivation. Three constructs related to motivation were identified in the literature and were used in this research study. The three constructs related to motivation were intrinsic goal orientation, extrinsic goal orientation, and task value. Intrinsic goal orientation refers to the degree to which one perceives his/herself to be participating in a task because the task itself is perceived as challenging and one that arouses curiosity. Extrinsic goal orientation refers to degree to which one perceives his/herself to be participating in a task because the task itself is connected with a desired external motivator, e.g., a high course grade or a reward. Task value refers to the degree to which one perceives his/herself to be participating in a task because the task itself is perceived to be important. The motivation section of the survey consisted of twelve items, with four items for each of the three motivation constructs: intrinsic goal orientation, extrinsic goal orientation, and task value (see Table 9).

Table 9: Survey items used to measure motivation construct

Construct	Survey Item
Intrinsic goal orientation	1. I prefer [type of session] that are challenging so I can learn new things. 2. I prefer [type of session] that arouses my curiosity, even they are difficult. 3. I prefer [type of session] that I will learn something from even if they require more work. 4. I prefer [type of session] that I can learn something from even if they do not guarantee a good grade.
Extrinsic goal orientation	1. Learning from [type of session] helps prepare me for tests. 2. Learning from [type of session] helps me get good grade on tests. 3. I participate in [type of session] because I am supposed to. 4. I prefer [type of session] because I am sure I can do them.
Task value	1. As a result of [type of session], I believe that I will able to use what I have learned in other courses. 2. It is important for me to learn what is taught in [type of session]. 3. I think that what I have learned from [type of session] is useful for me to know. 4. As a result of [type of session], I believe that I can apply what I have learned to real-world problems.

Note: the phrase, “type of session,” was replaced with a particular type session e.g.: collaborative or simulation session.

The survey used to measure the enjoyment construct was developed on the basis of previous research conducted by Berg (2007) and Pekrun et al. (2002). In this research study, enjoyment was defined as the degree to which a participant perceived his/herself to be participating or performing a task because the task itself was fun and/or enjoyable. The enjoyment construct consisted of four items (see Table 10).

Table 10: Survey items used to measure enjoyment

Construct	Survey Item
Enjoyment	1. I enjoy participating in [type of session]. 2. I feel that time flies when I participate in [type of session]. 3. After finishing [type of session], I look forward to the next class. 4. I would like to spend more time on [type of session].

Note: the phrase, “type of session,” was replaced with a particular type session e.g.: collaborative or simulation session.

Both enjoyment and motivation survey items were combined and distributed to participants (group one and group two) at one time. Participants responded to survey items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). A summary of the three dependent research variables and survey administration details are provided in Table 11.

Table 11: Summary of dependent research variables details

Research Variable	Research Instrument	When/how Assessment Completed	Respondents
Learning	Content knowledge tests (Jidoka1, Jidoka2, Jidoka3, Pull1, Pull2, and Pull3)	Before collaborative sessions, after collaborative sessions, and after simulation sessions	Participants in group one
Self-efficacy beliefs	Self-efficacy beliefs survey (Jidoka2, Jidoka3, Pull2, Pull3, Self-efficacy beliefs/Attitude-Collaborative, and Self-efficacy beliefs/Attitude-Simulation)	After collaborative sessions and after simulation sessions	Participants in group one Participants in group two
Attitudes	Attitude survey (Attitude-Collaborative, Attitude-Simulation, Self-efficacy beliefs/Attitude-Collaborative, and Self-efficacy beliefs/Attitude-Simulation)	After collaborative sessions and after simulation sessions	Participants in group one Participants in group two

For participants in group one, attitude surveys were distributed to participants at two different times: after collaborative sessions and after simulation sessions during the ninth week of Fall term in 2010 and 2011. Participants in group two responded to two surveys that included both self-efficacy beliefs and attitude items after a collaborative session and after a lab simulation session. Participants responded to all survey items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). Each survey took approximately 10-15 minutes to complete.

3.7 **Tests of Validity and Reliability**

3.7.1 **Research Instrument Validity**

Campbell and Stanley (1966) defined external validity as asking “the question of generalizability: to what populations, settings, treatment variables and measurement variables can this effect be generalized.” For this research study, the research participants were undergraduate and/or graduate students who had direct experience learning about lean principles and methods as a result of enrolling in a course where lean manufacturing principles were covered. These courses used traditional teaching methods (e.g., lecture notes, PowerPoint presentations, textbooks, slides) and nontraditional teaching methods (e.g. collaborative activities and simulations). As the research study was conducted in an actual higher education classroom setting, rather than using an experimental setting, the research findings can reasonably be generalized to other similar settings.

Content validity of the self-efficacy beliefs and attitudes (intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment) survey items were assessed. The content validity of these items was evaluated by five subject matter experts, who have experience in developing surveys. Four questions were asked for each survey items. First, respondents were asked to rate each question using a 5-point Likert scale. A 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree was used for all self-efficacy beliefs and attitudes survey items (See Appendix E). The content validity of the items were then evaluated using the content validity ratio (CVR) (Lawshe, 1975). The value of CVR ranges between +1 to -1. A value of CVR below 0.49 indicates unacceptable content validity. On the other hand, a value of CVR that is 1.00 indicates high content validity. The CVR can be calculated as shown in Equation 1.

$$CVR = \frac{(na)-(N/2)}{N/2} \tag{1}$$

Where na is the number of experts who agree or strongly agree, and N is the total number of experts participating. The results of the content validity analyses of the self-efficacy beliefs and attitudes survey items are summarized in Appendix E.

3.7.2 **Research Instrument Reliability**

Keyton (2001) defined reliability as the “consistency or stability of the measurement.” Internal reliability measures the consistency among survey items that test the same concept. In this research study, Cronbach’s alpha was used to assess the internal reliability of survey items used for individual constructs. Cronbach’s alpha ranges from 0 to 1. A Cronbach’s alpha value of 0.7 or more is considered satisfactory according to Nunnally (1978) and Garson (2010). A Cronbach’s alpha value of 0.5 or above is considered acceptable by Bowling (1977). Although, the internal reliability of the MSLQ measurements was reported previously using Cronbach’s alpha (with values ranging from 0.62 to 0.93), each set of survey items was evaluated using the data collected for this research study. Cronbach’s alpha was calculated for each variable or construct as appropriate, (e.g., self-efficacy beliefs, intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment).

3.8 **Analysis Details**

Data were analyzed using SPSS software version 14.0 and Microsoft Excel 2010. The analysis procedures used in this research study are described next.

3.8.1 **Descriptive Statistics**

Excel was used to calculate descriptive statistics for each variable. Specifically, the mean, median, mode, and the standard deviation for each variable were calculated. All variables are defined in Table 12. The model for each hypothesis is summarized in Table 13.

Table 12: Research variables and definitions

Type of Variables	Research Variables	Definition
Independent variables	Type of session	The form of teaching used, types of knowledge transmitted, and types of participation.
	Background knowledge	An individual's level of background knowledge and skill in a particular content/subject area.
Dependent variables	Learning	The knowledge, skills, and abilities that an individual demonstrates as a result of what is learned.
	Self-efficacy beliefs	An individual's belief in one's own ability to perform a task and/or apply what one has learned as a result of participating in a particular type of session.
	Attitudes	The way an individual feels, thinks, and reacts as a result of participating in a particular type of session.
	Motivation	The desire to participate in tasks and/or activities.
	Enjoyment	The degree of positive feelings resulting from an experience.

Q-Q plots were created for each research variable to determine whether or not the data were distributed normally before testing the models using parametric analysis. The analyses performed to test each hypothesis are discussed next.

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Table 13: Summary of statistical tests used to test the research hypotheses

Hypothesis	Statistical Tests
H1a: Collaborative sessions do not affect learning as measured by learning outcome achievement in group one participants.	$H_o: \mu_{Jidoka2} - \mu_{Jidoka1} = 0$ $Ha: \mu_{Jidoka2} - \mu_{Jidoka1} \neq 0$ $H_o: \mu_{pull2} - \mu_{pull1} = 0$ $Ha: \mu_{pull2} - \mu_{pull1} \neq 0$
H1b: Simulation sessions do not affect learning as measured by learning outcome achievement in group one participants.	$H_o: \mu_{Jidoka3} - \mu_{Jidoka2} = 0$ $Ha: \mu_{Jidoka3} - \mu_{Jidoka2} \neq 0$ $H_o: \mu_{pull3} - \mu_{pull2} = 0$ $Ha: \mu_{pull3} - \mu_{pull2} \neq 0$
H1c: The type of session does not affect learning as measured by learning outcome achievement in group one participants.	$H_o: d_{Jidoka3-Jidoka2} - d_{Jidoka2-Jidoka1} = 0$ $Ha: d_{Jidoka3-Jidoka2} - d_{Jidoka2-Jidoka1} \neq 0$ $H_o: d_{pull3-pull2} - d_{pull2-pull1} = 0$ $Ha: d_{pull3-pull2} - d_{pull2-pull1} \neq 0$ d = gain scores
H2 : Simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy beliefs survey scores	$H_o: \mu_{self\text{-}efficacy\ beliefs\_simulation} - \mu_{self\text{-}efficacy\ beliefs\_collaborative} = 0$ $Ha: \mu_{self\text{-}efficacy\ beliefs\_simulation} - \mu_{self\text{-}efficacy\ beliefs\_collaborative} \neq 0$
H3 : Simulation sessions do not affect attitudes as measured by motivation and enjoyment	$H_o: \mu_{motivation\_simulation} - \mu_{motivation\_collaborative} = 0$ $H_a: \mu_{motivation\_simulation} - \mu_{motivation\_collaborative} \neq 0$

Hypothesis	Statistical Tests
	$H_o : \mu_{enjoyment\_simulation} - \mu_{enjoyment\_collaborative} = 0$ $H_a : \mu_{enjoyment\_simulation} - \mu_{enjoyment\_collaborative} \neq 0$
H4a: The level of background knowledge does not affect learning as measured by learning outcome achievement in group one participants	$H_o : \mu_{low\text{-}level\ lean\ knowledge} = \mu_{high\text{-}level\ lean\ knowledge}$ $H_a : \mu_{low\text{-}level\ lean\ knowledge} \neq \mu_{high\text{-}level\ lean\ knowledge}$
H4b: The level of background knowledge does not affect attitudes as measured by motivation and enjoyment survey scores	$H_o : \mu_{low\text{-}level\ motivation} = \mu_{high\text{-}level\ motivation}$ $H_a : \mu_{low\text{-}level\ motivation} \neq \mu_{high\text{-}level\ motivation}$ $H_o : \mu_{low\text{-}level\ enjoyment} = \mu_{high\text{-}level\ enjoyment}$ $H_a : \mu_{low\text{-}level\ enjoyment} \neq \mu_{high\text{-}level\ enjoyment}$
H5 : There is no relationship between type of session, self-efficacy beliefs, background knowledge and learning in group one participants	Y {Learning (Jidoka or pull)} = $\beta_0 + \beta_1$.type of session + β_2 self-efficacy beliefs + β_3 background knowledge **Note**: Type of sessions (0 = collaborative, 1= simulation)
H6 : There is no a relationship between type of session, self-efficacy beliefs, background knowledge, and attitudes in group one participants	Y {Learner attitudes (motivation or enjoyment)} = $\beta_0 + \beta_1$.type of session + β_2 self-efficacy beliefs + β_3 background knowledge

3.8.2 **Paired Sample T-test on Learning**

The 60 multiple-choice questions were designed to measure learning related to two lean methods: Jidoka and pull production. The following hypotheses were tested using paired sample t-tests:

H1a: *Collaborative sessions do not affect learning as measured by learning outcome achievement in group one participants.*

A paired sample t-test was conducted to test Hypothesis 1a (H1a). A paired sample t-test was used to determine whether a significant difference exists in mean learning outcome achievement scores after participating in collaborative sessions. The independent variable is the collaborative sessions. The dependent variable is learning, as measured by individual learning outcome achievement scores.

H1b: *Simulation sessions do not affect learning as measured by learning outcome achievement in group one participants.*

A paired sample t-test was conducted to test Hypothesis 1b (H1b). A paired sample t-test was used to determine whether a significant difference exists in mean learning outcome achievement scores after participating in simulation sessions. The independent variable is the simulation sessions. The dependent variable is learning, as measured by individual learning outcome achievement scores.

H1c: *The type of session does not affect learning as measured by learning outcome achievement in group one participants.*

A paired sample t-test was conducted to examine differences in learning gains between four learning outcomes for each type of session (collaborative and simulation) for the entire set of group one participants. The mean difference between a participant's score was used to measure changes in learning. The different surveys were given before and/or after different types of session. The independent variable is the type of session. The dependent variable is learning, as measured by individual learning outcome achievement scores. Figure 6 summarizes the timing and overall research study design for testing H1a, H1b, and H1c.

Survey Administration Timing for Jidoka Methods:				
O	**X**	**O**	**X**	**O**
(Pretest) using Jidoka1	(Collaborative)	(Posttest) using Jidoka2	(Simulation)	(Posttest) using Jidoka3
Survey Administration Timing for Pull Production Methods:				
O	**X**	**O**	**X**	**O**
(Pretest) using Pull1	(Collaborative)	(Posttest) using Pull2	(Simulation)	(Posttest) using Pull3

Figure 6: Survey administration timing for learning outcome achievement

3.8.3 **Paired Sample T-test on Self-efficacy Beliefs and Attitudes.**

The following hypotheses were tested using a paired sample t-tests:

H2: *Simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy beliefs survey scores.*

A paired sample t-test was conducted to test Hypothesis 2 (H2). A paired sample t-test was used to determine whether a significant difference exists in mean self-efficacy beliefs survey scores after participating in simulation sessions. The independent variable is the simulation session. The dependent variable is self-efficacy beliefs, as measured by self-efficacy beliefs survey scores. For participants in group one, four self-efficacy beliefs surveys were used to measure an individual's beliefs in his/her own ability to perform a task and/or to apply what he/she learned from two types of sessions (collaborative and lab simulation sessions) on two lean principles (Jidoka and pull production system). Participants in group two responded two self-efficacy beliefs surveys for a particular type of session including collaborative and lab simulation. The paired sample t-tests were conducted to explore if there were differences in the level of self-efficacy beliefs after participating in a particular type of session.

H3: *Simulation sessions do not affect learner attitudes as measured by learner motivation and enjoyment survey scores.*

A paired sample t-test was conducted to test Hypothesis 4 (H4). A paired sample t-test was used to determine whether a significant difference exists in mean motivation and enjoyment survey scores after participating in simulation sessions. The independent variable is the simulation sessions. The dependent variable is learner attitudes, as measured by motivation and enjoyment survey scores. Paired sample t-tests were also used to identify statistically significant differences between motivation and enjoyment for different types of sessions. Figure 7 graphically summarizes the timing and overall design of the research study for determining the impact of session type on self-efficacy beliefs and attitudes.

Survey Administration Timing for Self-efficacy beliefs:

X	**O**	**X**	**O**
(Collaborative) or (Simulation)	(Jidoka2/Pull2)	(Simulation) or (Collaborative)	(Jidoka3/Pull3)

Survey Administration Timing for Attitudes:

X	**O**	**X**	**O**
(Collaborative) or (Simulation)	(Attitude-Collaborative) (Attitude-Simulation)	(Simulation) or (Collaborative)	(Attitude-Simulation) (Attitude-Collaborative)

Figure 7: Survey administration timing for self-efficacy beliefs and attitudes

3.8.4 Analysis of Variance (ANOVA)

The following hypotheses were tested using ANOVA:

H4a: *The level of background knowledge does not affect learning as measured by learning outcome achievement in group one participants.*

ANOVA was conducted to test Hypothesis 4a (H4a). ANOVA was used to determine whether a significant difference exists in mean learning outcome achievement scores for learners with low and high levels of background knowledge after participating in collaborative and simulation session. Hypothesis 4a (H4a) was used to examine the relationship for research variables for participants in group one only. The independent variable is the level of learner background knowledge. The dependent variable is learning.

H4b: *The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores in group one participants.*

ANOVA was conducted to test Hypothesis 4b (H4b). ANOVA was used to determine whether a significant difference exists in mean motivation and enjoyment survey scores for learners with low and high levels of background knowledge. Hypothesis 4b (H4b) was used to examine the relationship for research variables for participants in group one only. The independent variable is the level of learner background knowledge. The dependent variable is learner motivation and enjoyment.

3.8.5 **Linear Regression**

The following hypotheses were tested using linear regression:

H5: *There is no relationship between type of session, self-efficacy beliefs, background knowledge, and learning in group one participants.*

Linear regression was conducted to test Hypothesis 5 (H5). Linear regression was used to test for a possible relationship between four variables: type of session, self-efficacy beliefs, background knowledge, and learning. Hypothesis 5 (H5) was used to examine the relationships for participants in group one only. The independent variables are the type of session, self-efficacy beliefs, and background knowledge. The dependent variable is learning.

H6: *There is no relationship between type of session, self-efficacy beliefs, background knowledge, and attitudes in group one participants.*

Linear regression was conducted to test Hypothesis (H6a) of the research. Linear regression was used to test for a possible relationship between four variables: type of session, self-efficacy beliefs, background knowledge, and learner attitudes. Hypothesis 6a (H6a) was used to examine the relationships for participants in group one only. The independent variables are the type of session, self-efficacy beliefs, and background knowledge. The dependent variable is learner attitudes. Table 14 present a summary of the research hypotheses, research variables, and analyses.

Table 14: Summary of research hypotheses, research variables, and analyses

Research Hypothesis	Research Variable	Analysis
H1a: Collaborative sessions do not affect learning as measures by learning outcome achievement in group one participants	Learning	Paired t-test
H1b:Simulation sessions do not affect learning as measures by learning outcome achievement in group one participants	Learning	Paired t-test
H1c:The type of session does not affect learning as measured by learning outcome achievement in group one participants	Learning	Paired t-test
H2:Simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy beliefs survey scores.	Self-efficacy beliefs	Paired t-test
H3:Simulation sessions do not affect learner attitudes as measured by learner motivation and enjoyment survey scores.	Attitudes	Paired t-test
H4a:The level of background knowledge does not affect learning as measured by learning outcome achievement in group one participants.	Learning	Analysis of variance (ANOVA)
H4b:The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores in group one participants.	Attitudes	ANOVA
H5:There is no relationship between type of session, self-efficacy beliefs, background knowledge, and learning in group one participants	Type of session, self-efficacy beliefs, background	Regression analysis

Research Hypothesis	Research Variable	Analysis
	knowledge, and learning	
H6: There is no relationship between type of session, self-efficacy beliefs, background knowledge, and attitudes in group one participants	Type of session, self-efficacy beliefs, background knowledge, and attitudes	Regression analysis

The findings of this research study are presented in manuscript format. Chapter 4 and Chapter 5 were already been submitted as conference paper; whereas, Chapter 6 and Chapter 7 have been prepared for submittal to two different journals. The first manuscript (Chapter 4) examines the effect of using a role-playing simulation (called the Beer Distribution Game) on learner self-efficacy beliefs and attitudes. This paper also explores the relationship between self-efficacy beliefs and attitudes towards the use of Beer Distribution Game. The second manuscript (Chapter 5) examines the effect of a role-playing simulation (called TimeWise Simulation) on the learning of lean principles and methods and investigates the relationship between learner self-efficacy beliefs and knowledge resulting from the use of the TimeWise Simulation. The third and fourth manuscripts (Chapter 6 and Chapter 7) examine the effect of learner perceptions and learning achievement resulting from the use of collaborative and simulation sessions on learning lean manufacturing principles and methods in group one participants and in group two participants, respectively. Each of the four different manuscripts are presented next.

AN INVESTIGATION OF THE IMPACT OF A ROLE-PLAYING SIMULATION ON SELF-EFFICACY BELIEFS AND ATTITUDES

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Proceedings of the 2011 Industrial Engineering Research Conference (Best paper award)

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4. An Investigation of the Impact of a Role-playing Simulation on Self-efficacy beliefs and Attitudes

4.1 **Abstract**

The purpose of this paper is, first, to examine the effects of a well-known role-playing simulation (called the Beer Distribution Game) on self-efficacy beliefs and attitudes, and second, to explore the relationship between self-efficacy beliefs and attitudes towards the game. The Beer Distribution Game should help learners understand supply chain system dynamics. Theories regarding self-efficacy beliefs and attitudes have attracted researchers for over a decade. Previous researchers have indicated that self-efficacy beliefs influence learner performance. The learner's attitude is another factor that is thought to affect learning. However, there is little research on the relationship between self-efficacy beliefs and attitudes towards role-play simulations. In this study, data related to self-efficacy beliefs and attitudes were collected. A survey was distributed to students who participated at the end of a Beer Distribution Game session. The items on the survey were modified from the Motivated Strategies for Learning Questionnaire (MSLQ). The implications of the results are analyzed, and the relationship between self-efficacy beliefs and attitudes is also discussed.

4.2 **Keywords**

Beer Distribution Game, supply chain, role-playing simulattion, self-efficacy beliefs, attitudes.

4.3 **Introduction**

The interest in role-playing simulation has increased in academic areas as a means for improving student learning. Role-playing is considered to be a part of a wider set of techniques collectively known as simulation and gaming. McGuire and Priestley (1981) defined a role play as “a make-believe representation of some real-life event, carried out in order to help participants get better at managing the event itself,” p.87).

Many studies have found that role-playing and simulation have a positive influence on both teaching and on student learning (Armstrong, 2003; Fang, Cook, & Hauser, 2007; Francis & Byrne, 1999; Joyner & Young, 2006). For example, Liu (2007) used role-play activities as a teaching technique to motivate college students to learn to speak English. That study consisted of two groups of students: a target group and a control group. Approximately 20 students were participants in each group. Students were freshmen at Beijing City University; all had the same English fluency level at the beginning of the study. Students in the role-play class were asked to spend about 25 minutes doing role-play activities in each 45-minute lesson; whereas, students in the non-role-play class were asked to complete an oral English test in each lesson. Data were collected through three instruments: observation notes, questionnaires, and interview notes. The study showed that role-play activities increased student interest in speaking English. Furthermore, students in role-play activities were willing to speak English during the activities; whereas, students in non-role-play activities wanted to speak English only because of the tests. Johnson et al.

(2003) applied a role-play technique using simulation (called TimeWise Simulation) in teaching process design and lean principles at Worcester Polytechnic Institute. In the simulation, students worked together to assemble types of two clocks, a blue clock and a black clock, in the most profitable way possible. The simulation allowed the students to think and act as employees. Students were assigned specific roles such as hand assembly, material handling, production scheduling, warehouse clerk, and inspector. Students were able to observe the factory processes while working in these specific roles and were then able to develop ideas to improve the process. The simulation also provided students with the opportunity to apply knowledge and skills learned in the classroom to a simulated environment.

Among the role-playing simulations that have been used successfully is the role-playing simulation called the Beer Distribution Game. This game has grown to become one of the most recognized simulations used for teaching operations management and supply chain management concepts and has been used since the early 1960s. A group of professors at MIT’s Sloan School of Management developed the game to introduce learners to key concepts of supply chain management (Sterman, 1984). The Beer Distribution Game consists of four functions: the retailer, the wholesaler, the distributor, and the factory (see Figure 8).

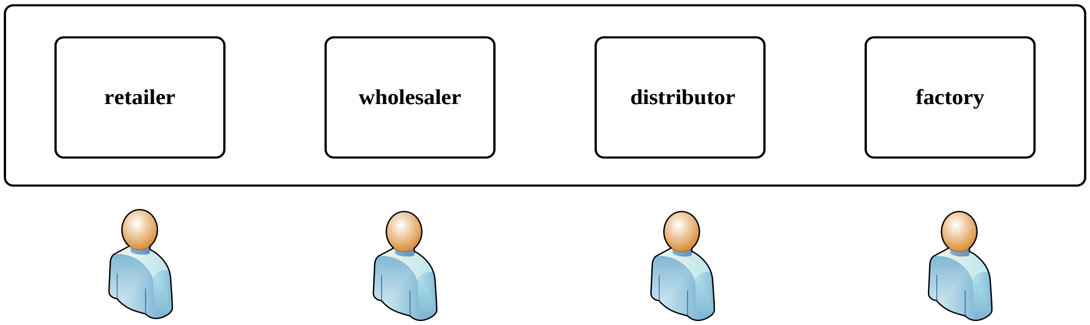

Figure 8: The four stages of the beer distribution chain

During Beer Distribution Game sessions, participants on each team are assigned a different role (e.g. retailer, wholesaler, distributor, and factory). Each team's goal is to minimize their costs, and each team competes against other teams. Order information is moved from upstream to the next stage of the beer distribution chain using the pull principle. The game starts with the raw materials at brewery, the first position of the beer distribution chain. Then beer is distributed at the second position, the distributor. The distributor delivers the beer to the wholesaler, the third position, to meet the distributor's demand. The retailer, in the last position, receives beer from the distributor, and finally the retailer sells the beer to the customers based on demand. The participants are asked to record inventory levels, backlogs, and orders placed with the supplier each week. During the game sessions, participants are not allowed to communicate with each other. Discussion takes place at the end of the simulation sessions. Studies have found that the simulation creates a realistic situation that provides participants with a better understanding of the critical importance of supply chain logistics in creating competitive advantage (Haartveit & Fjeld, 2002; Kumar, Chandra & Seppanen, 2007).

Although many studies have found that role-playing simulations have a direct impact on learner outcomes, self-efficacy beliefs and attitudes have been known to play an important role in learner performance and outcome. According to Bandura (1977), self-efficacy beliefs are the beliefs that one has the capability to learn or perform behaviors with respect to a specific task or situation. Bandura (1977) stated that people learn not only through their own experiences but also from observing others perform and the outcomes, and then they copy those behaviors. Likewise, people with a high level of self-efficacy beliefs not only believe that they can complete a task but they also work harder and show more persistence, leading to greater success. On the other hand, people with low levels of self-efficacy beliefs believe that they cannot do or complete a task and try to avoid it (Siegle, 2000).

Studies have shown that self-efficacy beliefs strongly relates to academic performance. For example, Lorsbak and Junks, (1999) studied the impact of self-efficacy beliefs on the learning environment. The study found that self-efficacy beliefs regarding academic performance are an important key in improving the learning environment as well as student outcomes. Understanding student academic self-efficacy beliefs concepts has the potential to lead to changes in student perceptions about the learning environment. Mahyuddin et al. (2006) explored the relationship between student self-efficacy beliefs and student achievement in the English language. A total of 1,146 students from eight secondary schools participated in this research study. The participants came from various countries, including Malaysia, China, and India. The study focused on four areas: 1) determining the level of self-efficacy beliefs among students related to the English language; 2) determining the difference in the level of self-efficacy beliefs between males and females; 3) determining the difference in the level of self-efficacy beliefs between students from different locations (urban and rural schools); and 4) determining the relationship between student self-efficacy beliefs and English language achievement. The study found that a total of 43.6 % of students who had a low level of self-efficacy beliefs in their English language skills believed that English was difficult for them, resulting in less motivation to learn. On the other hand, the group of students who had a high level of self-efficacy beliefs in their English language skills demonstrated better performance in learning outcomes compared with the group of students who had lower levels of self-efficacy beliefs. Similarly, Lent et al. (2008) studied the level of self-efficacy beliefs of first-year and second-year engineering students in introductory engineering classes. The study found that there was a significant relationship between self-efficacy beliefs and student outcomes, expectations, interests, and persistence.

Finally, some studies have found that learner attitudes positively affect learning. Student learning attitudes are classified into two general areas: student motivation and student enjoyment. Deci and Ryan (2000) defined motivation as “a set of behaviors that will bring about desired outcomes or goals.” This study focused on three attitudes: intrinsic goal orientation, task value, and enjoyment. People with intrinsic goal orientation perceive themselves to be participating in a task because of the challenge and curiosity. People motivated by task value perceive themselves to be participating in a task because of their interest and because they believe that the task is important. Finally, people choose to participate in a task because the task itself is interesting and enjoyable. These attitude variables are particularly important in helping us to better understand why learners engage in learning activities. Abdelfattah (2010) found a positive relationship between motivation levels and student performance, as measured on low-stake examinations. Tella (2007) studied the impact of high and low-level motivation on student academic achievement in mathematics among secondary school students in Nigeria. Four hundred fifty secondary school students from ten schools participated in this study. Data were collected using a modified motivation for occupational preference scale. The results showed that there was correlation between student motivation and learning achievement in mathematics.

The purpose of this paper is to explore the effects of the Beer Distribution Game on self-efficacy beliefs and attitudes. It was expected that students who played the Beer Distribution Game would demonstrate a high level of confidence in their knowledge of supply chain concepts and also have a positive attitude towards the Beer Distribution Game activities. In addition, it was hypothesized that there would be a positive correlation between self-efficacy beliefs and the attitudes of individual learners in three areas: intrinsic goal orientation, task value, and enjoyment. A pilot study was completed to evaluate the impact of this role-playing simulation on student self-efficacy beliefs and attitudes. The results of the pilot study are presented, along with the details of the assessment methodology used. The following research hypotheses were developed:

- There is no relationship between self-efficacy beliefs and student attitudes (in three areas: intrinsic goals, task value, and enjoyment) resulting from the playing of the Beer Distribution Game.
- There are no relationships among the three areas of student attitudes (intrinsic goals, task value, and enjoyment) resulting from the playing of the Beer Distribution Game.

4.4 **Methods**

4.4.1 **Participants**

A group of fifteen students participated in this pilot study. All participants were undergraduate (junior or senior year) or graduate students from the Industrial Engineering or Mechanical Engineering programs at Oregon State University.

4.4.2 **Procedure and Instruments**

At the end of the Beer Distribution Game, participants were asked to complete a modified version of the Motivated Strategies for Learning Questionnaire (MSLQ) (1993) in the areas of student self-efficacy beliefs, intrinsic goal orientation, and task value. The internal reliability of the MSLQ measurements has been reported previously. Cronbach's alpha values from previous studies ranged from 0.62 to 0.93. The MSLQ is a self-report instrument used to measure student motivational beliefs and self-regulated learning behaviors in classroom contexts. The MSLQ has been successfully used by many researchers in higher education (Higgins, 2000; Mullen &

Tallent-Runnels, 2006). In addition, items measuring student attitudes in the area of enjoyment were developed based on previous research by Berg (2007) and Pekrun et al. (2002).

4.4.3 **Self-efficacy Beliefs**

For this study, self-efficacy beliefs were defined as student beliefs in their own ability to perform a task and/or to apply what they learned from the Beer Distribution Game activities in the future. To assess the level of self-efficacy beliefs, four items related to student self-efficacy beliefs were used (see Table 15). Participants responded to survey items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree).

4.4.4 **Attitudes**

Attitudes were defined as the way students feel, think and react as a result of Beer Distribution Game activities. Three constructs (intrinsic goal orientation, task value, and enjoyment) were used to measure student attitudes. Intrinsic goal orientation can be defined as a student decision to engage in a task because of a desire to satisfy his/her curiosity and because he/she finds the tasks themselves interesting and challenging (Printrich et al., 1993). On the other hand, task value can be defined as a student decision to engage in a task because the task itself is important and useful in his/her life (Garcia, Mckeachie, Pintrich, & Smith, 1991). Finally, the third construct, enjoyment, can be defined as the degree of student enjoyment toward a task.

The attitude section of the survey consisted of 12 items, with four items for each of the three constructs. Participants were asked to rate their level of agreement with these 12 items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). Table 15 shows the survey items used in this study.

Table 15: Survey items used to measure student self-efficacy beliefs and attitudes

Variables	Item no.	Item Content
Self-efficacy beliefs	1	The Beer Distribution Game increased my confidence in my own understanding of Supply Chain Concepts.
	2	I am certain I understand the most difficult concepts used in the Beer Game today.
	3	As a result of the Beer Distribution Game, I can now explain to my friends what I have learned about Supply Chain Management.
	4	I am certain I can master the skills being taught in the Beer Distribution Game.
Student attitudes		
1) Intrinsic goal orientation	1	I prefer learning activities that are challenging so I can learn new things.
	2	I prefer learning activities that arouse my curiously, even if they are difficult.
	3	I prefer learning activities that I will learn something from even if they require more work.
	4	I prefer learning activities that I can learn something from even if they do not relate to my grade.
2) Task value	1	As a result of the Beer Game, I believe that I will able to use what I have learned in other courses.
	2	It is important for me to learn what is taught by the Beer Game activities.
	3	I think that what I have learned from the Beer Game is useful.
	4	As a result of the Beer Game, I believe that I can apply what I have learned to real-world problems.
3)Enjoyment	1	I enjoyed participating in this learning session.
	2	I felt that time flew when I participated in this learning session.
	3	I look forward to the opportunity to attend another learning session in the future.
	4	I would like to spend more time on this learning session.

4.5 **Results**

Cronbach's alpha coefficient for each variable (e.g. student self-efficacy beliefs, intrinsic goal orientation, task value, and enjoyment) was calculated to check internal reliability of the survey items using response data from the participants in this study. SPSS 14.0 was used to complete all analyses. After analyzing the data, one item from the student attitude construct, in area of task value (As a result of the Beer Game, I believe that I will able to use what I have learned in other courses) and one item from enjoyment (I would like to spend more time on this learning session) were deleted, because the Cronbach's alpha coefficient was less than 0.5 when these items were included.

Cronbach's alpha ranges from 0 to 1. A Cronbach's alpha coefficient of 0.7 or more is considered satisfactory by some authorities, Nunnally (2010) and Garson (1978), while a Cronbach's alpha coefficient of 0.5 or above is considered acceptable by Bowling (1997). The Cronbach's alpha coefficients for the modified set of items for student self-efficacy beliefs, intrinsic goal orientation, task value, and enjoyment were 0.613, 0.513, 0.810, and 0.615, respectively. Self-efficacy beliefs and intrinsic goal orientation retained four items. Task value and enjoyment retained three items. Each survey item was carefully checked for clarity and relevancy to make sure that it was logically representative to the purpose of the study. Feedback from experts in the field was used to examine the face validity of each survey items. Due to the very small number of study participants, factor analysis to test for construct validity was not completed. However, this is an area for future research.

Table 16 summarizes the descriptive statistics for each variable. The mean scores for all four survey variables (student self-efficacy beliefs, intrinsic goal orientation, task value, and enjoyment) are above the midpoint of the response scale. The results also showed that approximately 42% of participating students had no background content knowledge in supply chain concepts before participating in the Beer Distribution Game Simulation.

For student self-efficacy beliefs, the results indicated that most students agreed or strongly agreed that the Beer Distribution Game increased their confidence in their own understanding of supply chain concepts. Participants reported an increased understanding of supply chain concepts after participating in the Beer Distribution Game. The minimum score for this variable was 3.0, and the maximum was 4.5. The results indicate that students thought that the Beer Distribution Game was interesting and valuable. However, the data indicated that the Beer Distribution Game activities had little effect impact on student enjoyment.

Table 16: Summary descriptive statistics for each survey construct

Variables	n	Min.	Max.	Sum	Mean	SD
Self-efficacy beliefs	12	3.00	4.50	45.00	3.75	0.53
Intrinsic goal orientation	12	3.50	5.00	48.75	4.06	0.41
Task value	12	3.25	4.75	48.75	4.06	0.45
Enjoyment	12	2.25	3.50	36.75	3.06	0.30

A normal Q-Q plot was created for each variable in order to determine whether the data were normally distributed. Q-Q plots confirmed that the data were more or less normally distributed, as shown in Figure 9.

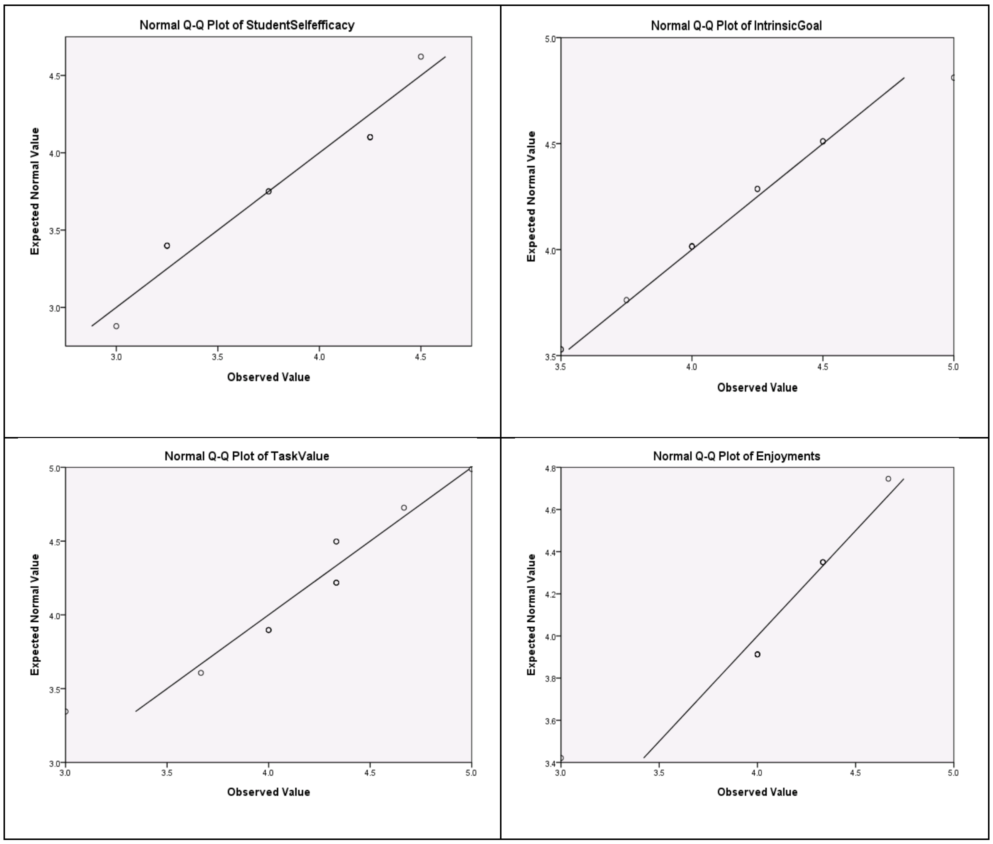

Figure 9: Q-Q plots for each variable

Pearson's correlation coefficient was used to explore the relationship between the variables measured in this study. The Pearson's correlation coefficient (r) was developed by Karl Pearson and is used to test the relationship and/or association between two variables. This coefficient can range from -1 to +1. When Pearson r values are close to +1, this indicates a positive relationship between the two variables.

Conversely, when the Pearson r values are close to -1, this indicates a negative relationship between the two variables. Correlations among student self-efficacy beliefs, intrinsic goal orientation, task value, and enjoyment were examined. The results are presented in Table 17.

Table 17: Summary correlations between survey variables

		Self-efficacy beliefs	Intrinsic goal Orientation	Task value	Enjoyment
Self-efficacy beliefs	Pearson Correlation	1	0.468	0.679*	-0.140
	Sig. (2-tailed)		0.125	0.015	0.664
	n	12	12	12	12
Intrinsic Goal orientation	Pearson Correlation	0.468	1	0.505	0.422
	Sig. (2-tailed)	0.125		0.094	0.172
	n	12	12	12	12
Task Value	Pearson Correlation	0.679*	0.505	1	0.074
	Sig. (2-tailed)	0.015	0.094		0.818
	n	12	12	12	12
Enjoyment	Pearson Correlation	-0.104	0.422	0.074	1
	Sig. (2-tailed)	0.664	0.172	0.818	
	n	12	12	12	12

Self-efficacy beliefs were found to be significantly correlated to task value ($r = 0.679$, $p < .05$). The positive relationship suggests that individuals with high self-efficacy beliefs who believe that they can learn or perform better in a given task are more likely to choose to engage in tasks that are important to them. There were no statistically significant correlations found between student self-efficacy beliefs and intrinsic goal orientation, nor between student self-efficacy beliefs and enjoyment. The results showed that there were no significant correlations between the various student attitudes constructs measured.

Moreover, the results from this study indicated positive outcomes from the experience. Students indicated that the activities allowed them to understand supply chain management through their own experience with the game. Students also suggested ways that the game could be changed to improve student learning. Some wanted to spend more time at the beginning discussing learning objectives. Some preferred to not see the status of other teams during the game.

4.6 **Recommendations**

This study provides some evidence of the benefits of using the Beer Distribution Game to teach supply chain concepts. The game appeared to increase student self-efficacy beliefs, as well as to positively impact student attitudes in task value. Future research should focus on the creation of role-play simulations and/or learning activities that promote student self-efficacy beliefs and knowledge. Additional research is also needed to find ways to increase the value of simulations and/or learning activities. In addition, student learning could be evaluated to determine whether performance has changed after participating in the Beer Distribution Game. Larger studies are also needed to increase the generalizability of the research findings.

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EVALUATION OF ROLE-PLAYING SIMULATION

ON LEAN PRINCIPLES AND METHODS

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5. Evaluation of a Role-playing Simulation on Lean Principles and Methods

5.1 Abstract

The study of role-playing simulation tools has attracted many scholars over the last decade. Using role-playing techniques in a simulation allows participants to build problem-solving abilities. The skills and abilities that participants learn can be later applied and transferred to a working environment. However, previous research has not identified factors that can influence participant learning resulting from role-playing simulations, specifically focused on lean principles and methods.

The purpose of this paper is overall to evaluate the impact of a role-playing simulation on the learning of lean principles and methods. Second, the study seeks to investigate the relationship between self-efficacy beliefs and knowledge. The impact of background knowledge on learning was also studied. The research participants were students enrolled in an upper division course, called Lean Manufacturing Systems Engineering. A pre-posttest design was used to assess student learning. Background knowledge and self-efficacy beliefs were also measured after students participated in a role-playing simulation. Significant differences in knowledge between groups of students based on background knowledge were not observed. However, students with less background knowledge showed larger improvements (gains) in knowledge than students with more background knowledge after participating in a role-playing simulation.

5.2 **Keywords**

Lean principles and methods, role-playing, simulation, Jidoka, pull production systems.

5.3 **Introduction**

Many studies have examined lean as one of the most successful improvement methodologies. The literature supports the benefits of implementing lean techniques to improve organizational outcomes. Due to the widespread and successful application of lean principles and methods, those who have been trained in implementing lean principles and methods have become more valuable in the workplace. According to Nambiar and Masel (2008), job applicants are increasingly being asked about their knowledge of lean principles. Lean principles and methods are traditionally taught in the higher education classroom through traditional teaching methods (Allen, 2000). Traditional teaching methods consist of lectures, textbooks, case studies, and/or exercises. Learning through a traditional teaching method may cause difficulties for some students attempting to understand and apply lean principles and methods. Each organization has unique set of product, process, people, and development needs. Learners often need to understand the complexities of a real production environment before being able to apply and/or select the suitable lean principles and methods. As a result, several nontraditional teaching methods have been developed for assisting learners in gaining a deeper understanding of lean principles and methods.

Although several studies have shown that using nontraditional teaching methods can improve learning, other factors, such as self-efficacy beliefs (Zimmerman, 2000; Hoffman & Spatariu, 2008) and background knowledge (Beskeni, Yousuf, Awang, & Ranjha, 2011), have been found to also influence how well students learn. A review of relevant literature on lean simulations, self-efficacy beliefs, and background knowledge is provided next.

5.4 **Literature Review**

5.4.1 **Lean Role-playing Simulations**

Nontraditional teaching methods, such as role-playing, hands-on exercises, hands-on projects, simulation and games, and computer games have been developed to keep participants engaged and to help participants gain a better understanding of subjects. For example, a role-playing simulation called the Beer Distribution Game was first used at MIT's Sloan School of Management to introduce and teach the concepts of supply chain management (Sterman, 1984). Similarly, Elbadawi et al. (2009) developed hands-on simulation exercises, known as the paper airplane factory, to help students understand four manufacturing strategies: craft production, push production, pull production, and Kanban production. Henry and LaFrance (2006) developed role-playing exercises to integrate sociological and communication aspects called socio-technical techniques into software engineering courses.

Using role-playing techniques in simulation tools is increasing in popularity among educators in recent years. TimeWise, Lean Enterprise Value (LEV), Lean

Lego[TM], and the Box Game are examples of role-playing simulations applied in industrial training, workplace training, and educational settings as supplements for or replacements for traditional teaching methods. Role-playing simulations can be an effective teaching and training tool because the role-playing simulations allow participants to think and act in a variety of roles, including, for example, the role of an employee. Alden (1999) defined role-playing as consisting of three major steps. First, participants are introduced to the purpose of the session. If the style of the role-playing requires participants (also called players) to act in the role, participants are told about the situation and setting for the role-playing. Second, the role-playing is conducted. Last, a discussion session is conducted at the conclusion of the role-playing.

The role-playing simulation that was used in this research study was TimeWise. TimeWise has been widely used primarily for professional training and in some higher education settings (Johnson, et al., 2003; Verma, 2003). TimeWise was developed by the Manufacturing Extension Partnership, Management Service, Inc. (MEP-MSI) in 2001. The main goal of TimeWise is to allow participants to work as a team and to encourage participants to apply lean knowledge to a simulated clock assembly line. The TimeWise simulation is usually played in four rounds. Participants experience traditional manufacturing in the first round and learn to apply lean manufacturing principles and methods during the second, third and fourth rounds. Each round takes approximately 15 minutes to complete and is followed by a group discussion.

In the TimeWise simulation, each participant acts as member of the TimeWise Company. Each participant is required to read a job description. Participants may be assigned a different task/role in each run of the simulation. The factory produces three types of clocks. Participants work in one of four different areas: suppliers (e.g., suppliers, quadrant vendor, hand vendor), manufacturing (e.g., material handler, face assembly, back assembly, clock assembly, hand assembly, kitter, inspection and rework), support (e.g., supervisor and industrial engineer), or front office (e.g., design engineer, sales representative, application engineer). Participants are expected to be able to observe the TimeWise process from different perspectives and to learn from the application of various lean principles and methods how to improve or redesign processes. Several lean principles and methods are presented at various points in the simulation, including pull production, poka-yoke, 5S, and visual workplace techniques. The number of positions/workstations in the TimeWise assembly line are adjusted for each round. Sample illustrations of the TimeWise simulation layout and activities are shown in Figure 10.

(a)

(b)

(c)

(d)

Figure 10: Example of TimeWise simulation layout and activities (a) TimeWise simulation layout (b) Work in process (WIP) (c) Face Assembly work station (d) A TimeWise simulation round in process

While there are plenty of previous studies that have focused on the development and application of role-playing simulations for educating trainees in lean principles and methods over the past decade, there is a need for studies that examine participant skill acquisition following the use of role-playing simulation for teaching lean principles and methods. For this research, learning related to skill development for two lean methods were studied: Jidoka and pull production systems. Jidoka, a Japanese term, can be translated as "automation with a human touch" is used to eliminate mistakes (Ohno, 1988). The second skill area studied was pull production systems. The pull production system is sometimes referred to as a "just-in-time production (JIT)." Pull production or "Pull" is a system in which planning and scheduling of production is based on customer orders. Jidoka and pull are lean methods that have been successfully applied to eliminate waste, reduce costs, and gain competitive advantage in both manufacturing and nonmanufacturing environments. In addition to looking at skill development and learning related to specific lean concepts, self-efficacy beliefs, and background knowledge have been identified by previous researchers as potentially important variables in the study of learning techniques. Previous research on both self-efficacy beliefs and background knowledge are presented next.

5.4.2 **Self-efficacy Beliefs**

The concept of self-efficacy beliefs was first introduced by Bandura in 1997. Self-efficacy beliefs can be described in many ways. For example, Bandura (1997) defined perceived self-efficacy beliefs as “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments, p.3.” Self-efficacy beliefs was described by Seifert (2004) as “a construct synonymous with confidence and refers to a person’s judgment about his/her capability to performance a task at a specified level of performance, p.137.”

The findings in the literature suggest that self-efficacy beliefs have a significant influence on both participant behavior and performance. Some examples of the effects of self-efficacy beliefs have been reported in previous studies on computer technology and in studies of personal performance (Multon, Brown, & Leant, 1991). Isman and Celikli (2009) studied the relationship between computer skills, different levels of self-efficacy beliefs, the years of computer usage and gender. The research results demonstrated a significant relationship between computer skills and the level of self-efficacy beliefs.

There is also evidence for a relationship between self-efficacy beliefs and performance. For example, Multon et al., (1991) used a meta-analysis to evaluate 36 research studies published from 1981-1988, which examined the relationship between self-efficacy beliefs and academic performance and persistence. The research analyzed data that were primarily collected from elementary, high schools, and college students. The research found that self-efficacy beliefs account for over 10% of the observed variance in academic performance. Similarly, Lunenburg (2011) studied the effect of individual employee self-efficacy beliefs on learning and performing tasks in the workplace. The research results found that self-efficacy beliefs contributed to learning, task performance, and individual goal-setting. The research findings also suggested that employees with high self-efficacy beliefs may be more capable of learning from training and tend to use what they have learned to enhance job performance. In contrast, Singh et al., (2010) studied the effect of computer self-efficacy beliefs on academic performance. The research results suggest that student computer self-efficacy beliefs had a negative impact on grade improvement. While, there have been a number of studies on the impact of self-efficacy beliefs, a relationship between self-efficacy beliefs and learning related to lean principles and methods has not been established. The role of background knowledge on student learning, based on previous research, will be discussed next.

5.4.3 **Background Knowledge**

Background knowledge has been found to be related to learning achievement (Stevens, 1980; DePaolo & McLaren, 2006). “Prior knowledge”, “background knowledge” and “existing content knowledge” are often found as interchangeable terms in the literature. The term background knowledge, used in this research study, was defined as all information and content knowledge of a particular lean concept that individual learners had at the time that a survey/test was conducted. Several researchers have examined the impact of background knowledge on academic performance. For example, Stevens (1980) studied the role of background knowledge on 108 ninth grade students’ English reading performance. The study was completed by administering a 100-item multiple choice quiz during a regular English period. The researchers found that background knowledge had a positive influence on academic achievement. DePaolo and McLaren (2006) studied the relationship between student attitudes and learning performance in an undergraduate business calculus course. The results found that the students who did not have background knowledge in calculus received a low/poor score on the exam, which tended to be related to negative attitudes toward the subject. Having provided an overview of lean role-playing simulation, self-efficacy beliefs, and background knowledge, the specific research questions for this study are detailed next.

The purpose of this paper is to examine the impact of the TimeWise Simulation on participant learning in two areas: Jidoka and pull. Research participants were enrolled in an upper division course entitled Lean Manufacturing Systems

Engineering at Oregon State University during the Fall of 2010. The relationship between self-efficacy beliefs and participant learning was investigated. The impact of background knowledge on student learning was also studied. Two primary research questions were developed and are explored in this paper. The research methods used in this study are described next.

- Does level of background knowledge have an impact on learning (Jidoka and pull methods)?
- Is there a relationship between self-efficacy beliefs, background knowledge, and lean knowledge (Jidoka and pull methods)

5.5 **Methods**

5.5.1 **Participants**

Thirty-two students were participants in this research study. Twenty-five students were undergraduates (junior or senior year) and eight students were graduate students in Industrial Engineering, Manufacturing Engineering, or Mechanical Engineering. All participants were enrolled in a course called Lean Manufacturing Systems Engineering at Oregon State University during the Fall of 2010

5.5.2 **Procedures and Instruments**

Participants were asked to complete four surveys called: Jidoka1, Jidoka2, Pull1, and Pull2. Jidoka1 and Pull1 each consisted of ten multiple-choice questions designed to measure participant background knowledge about one of two lean methods: Jidoka and pull. Jidoka1 and Pull1 were distributed prior to lectures in which these lean topics were discussed in class. Jidoka2 and Pull2 each consisted of ten multiple-choice questions on the lean concepts and six Likert scale items that were designed to measure participant self-efficacy beliefs. Jidoka2 and Pull2 were administered after students participated in a TimeWise role-playing simulation run in which the methods (Jidoka or pull) were covered.

5.5.3 **Background Knowledge and Learning Surveys**

A set of 40 multiple-choice items were used to measure participant background knowledge and learning related to two lean methods: Jidoka and pull. Examples of some of the multiple choice questions related to Jidoka and pull are included in Table 18.

5.5.4 **Self-efficacy Beliefs Survey**

Self-efficacy beliefs were defined as the level of confidence individuals have in their own capability to apply their knowledge and skill based on what they have learned from the TimeWise role-playing simulation. Specifically, students were asked to assess their ability to answer lean questions and solve problems related to the examples provided, their ability to teach lean content to peers, and their ability to apply what they learned to real-world problems. The self-efficacy beliefs items used were modified from the Motivated Strategies for Learning Questionnaire (MSLQ) (1993). The self-efficacy beliefs survey items were included on the survey distributed to participants after participating in the TimeWise role-playing simulation.

Participants responded to self-efficacy beliefs survey items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). Table 18 also includes the six self-efficacy beliefs items used for the study.

Table 18: Example of survey items used to measure student content knowledge and self-efficacy beliefs

Variables	Content Categories	Item Content
Jidoka	Background knowledge	1.________ means to stop the line automatically when something is wrong and then fix problems on the line. a. Poka-Yoke. b. Andon. c. Muda. d. Jidoka. 2. Which one of the following lean tools is used to prevent worker and machine error? a. Jidoka. b. Poka-Yoke. c. Andon. d. Muda.
	Knowledge	1. The ABC Company has many machines, and there are very few workers to operate the machines. _________ would be very useful to visually signal which machines are down. a. Poka-Yoke. b. Andon board. c. Jidoka. d. Muda. 2. ABC manufacturing requires a fixed number of operations within a process. Which one of the following lean tools can be used to improve the ABC manufacturing? a.Poka-Yoke. b.Andon board. c.Jidoka. d.All of the above.
Pull	Background Knowledge	1. What does the word "Kanban" mean? a.Continuous improvement. b.Card. c. Low inventory. d. Mistake proof. 2. __________ provides fast response to changes in production demand. a.A pull production system. b. A push production system. c. All of the above. d. None of the above.
	Knowledge	1. Which of the following is an example of a push production system? a. Dell allows customers to build their own computer specifications on the internet.

Variables	Content Categories	Item Content
		b. Workers at 7-Eleven will refill merchandise on the display shelves based only on what the customer takes from the shelves. c. A pre-cooked fast food company prepares food based on sales forecasts. d. None of the above. 2. Which of the following is **NOT** true about Kanban? a. In Kanban systems, a breakdown in the Kanban system can result in the entire production line shutting down. b. Kanban systems are suitable for products with short production runs and highly variable product demand. c. In pull systems, Kanban is used as a visual system for controlling production. d. None of the above.
Self-efficacy beliefs	Jidoka/pull methods	1. As a result of TimeWise Simulation, I believe that I will be able to respond to exam questions on Jidoka/pull production system. 2. The TimeWise Simulation increased my confidence in my own understanding of Jidoka concepts/concepts of a pull production system. 3. I am certain I understand the most difficult concepts used in the TimeWise Simulation activities today. 4. As a result of today's TimeWise Simulation, I have no doubt about my capability to do well on Jidoka/pull production system assignments. 5. As a result of today's TimeWise Simulation I can now explain to my friends what I have learned about Jidoka/pull production system. 6. I am certain I can master the skills being taught in the TimeWise Simulation today.

5.6 **Results**

Data were analyzed using SPSS (Version14.0) and Microsoft Excel 2010. In order to check the reliability of the research survey constructs, Cronbach's alpha coefficients for self-efficacy beliefs on two lean concepts (Jidoka and pull) were reviewed. Cronbach's alpha has a range between 0 and 1. Although the MSLQ has been shown to have good internal reliability in previous studies with values ranging from 0.62 to 0.93, the Cronbach's alpha coefficients were calculated to assess the reliability of the specific survey items used for this study. The Cronbach's alpha coefficients that were obtained in this research study were 0.885 and 0.862 for Jidoka self-efficacy beliefs and pull self-efficacy beliefs, respectively. The internal reliability of the survey was considered to be acceptable.

Table 19 summarizes the descriptive statistics for each variable, including the minimum, maximum, mean values, and standard deviations for the overall study group (n = 32 for the Jidoka surveys and n = 29 for the pull surveys). There were ten questions on the survey for background knowledge and ten questions each to measure learning of Jidoka and pull. The mean scores of the Jidoka background knowledge (Jidoka1) and learning (Jidoka2) were 4.69 and 7.56, respectively. On the other hand, the mean scores for the pull background knowledge (Pull1) and learning (Pull2) were 4.62 and 7.31, respectively.

The participant mean scores for both lean methods (Jidoka and pull) showed improvement between the first and second tests. The minimum score for participant self-efficacy beliefs on Jidoka and pull was 2.5 and 2.8, and the maximum self-efficacy beliefs score on Jidoka and pull was 4.8 and 5.0, respectively. Self-efficacy beliefs scores showed very little variation between participants.

Table 19: Summary descriptive statistics for each survey construct

Variable (survey)	n	Minimum	Maximum	Mean	SD
Background knowledge					
1) Jidoka (Jidoka1)	32	2	9	4.69	1.942
2) Pull (Pull1)	29	1	7	4.62	1.498
Self-efficacy beliefs					
1) Jidoka	32	2.5	4.8	3.78	0.573
2) Pull	29	2.8	5	4.05	0.450
Knowledge					
1) Jidoka (Jidoka2)	32	5	10	7.56	1.105
2) Pull (Pull2)	29	4	9	7.31	1.442

Q-Q plots for each research variable: (background knowledge, Jidoka and pull methods, self-efficacy beliefs, Jidoka and pull methods, and knowledge, Jidoka and pull methods are shown in Figure 11. The data appeared to be approximately normally distributed.

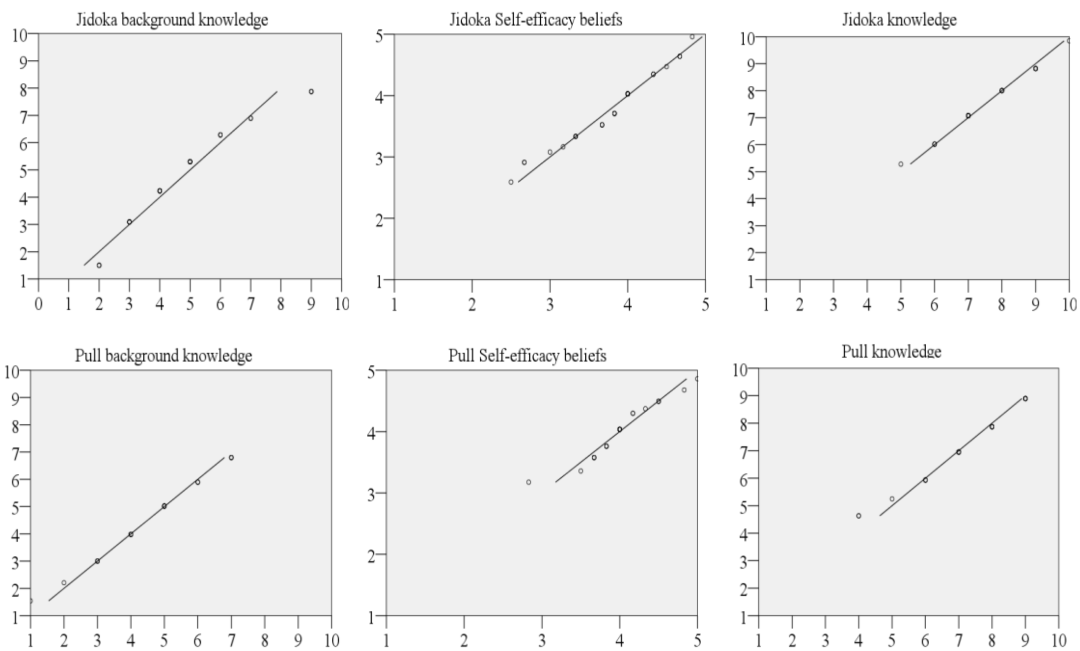

Figure 11: Q-Q plots for each variable

Descriptive statistics were reviewed and analysis of variance (ANOVA) was conducted to explore the effects of background knowledge on lean knowledge and to answer the first research question. ANOVA was used to determine whether any significant differences between groups of participants existed. Participants were divided into two groups to investigate the impact of Jidoka and pull background knowledge on individual lean knowledge. The mean score of participant background knowledge on both lean concepts was used to separate participants into two groups.

For Jidoka methods, participants were divided into two groups, one with low background knowledge (scores ≤ 4.69) and a second with higher background knowledge (scores > 4.69). A participant who received a Jidoka1 score below or equal to 4.69 was considered to have low background knowledge on Jidoka methods (low group), while the participant who received a Jidoka1 score above 4.69 was considered to have higher background knowledge on Jidoka methods. There were 13 participants in the low group and 16 in the high group related to Jidoka methods.

Similarly, the participants were also divided into two groups with low (scores ≤ 4.62) and high background knowledge (scores > 4.62). The participants who received Pull1 scores below or equal to 4.62 were considered to have low background knowledge on pull concepts. Whereas, the participants who received Pull1 scores above 4.62 were considered to have higher background knowledge (high group) on pull concepts. There were 13 participants in the low group and 16 in the high group related to pull concepts. The ANOVA results comparing knowledge after participating in the role-playing simulation for the low and high background knowledge groups for both Jidoka and pull concepts are summarized in Tables 20 and 21.

Gain scores were used to determine learning improvement between the two groups (low and high group for each lean method). The gain scores for each lean concept were calculated by subtracting the Jidoka1 score from the Jidoka2 score and the Pull1 score from the Pull2. As shown in Table 22 and 23, the average gain scores for the low and high background knowledge groups for both Jidoka and pull concepts were 4.37, 1.37, 3.69, and 1.87, respectively.

Table 20: Summary descriptive statistics for Jidoka knowledge and gain scores for low and high Jidoka background knowledge groups

Jidoka Background Knowledge		Jidoka Knowledge	Jidoka Gain Scores
Low-level	Mean	7.56	4.37
$\bar{x}$ = 4.69	n	13	
$J_{low} \leq \bar{x}$	SD	1.09	1.02
High-level	Mean	7.56	1.37
$J_{High} > \bar{x}$	n	16	
	SD	1.15	2.33

Table 21: Summary descriptive statistics for pull knowledge and gain scores for low and high pull background knowledge groups

Pull Background Knowledge		Pull Knowledge	Pull Gain Scores
Low-level	Mean	7.00	3.69
$\bar{x}$ = 4.62	n	13	
$P_{low} \leq \bar{x}$	SD	1.41	1.55
High-level	Mean	7.56	1.87
$P_{High} > \bar{x}$	n	16	
	SD	1.46	1.67

A p-value of 0.05 was used for all tests to determine whether or not groups were significantly different. No significant differences were found between low and high background knowledge groups in learning Jidoka methods (See Table 22). The analysis of gain scores, however, did identify significant differences in Jidoka gain scores (p = 0.000) between the two groups.

Table 22: Summary of ANOVA results for Jidoka knowledge and Jidoka gain scores for low and high Jidoka background knowledge groups

		Sum of Squares	df	Mean Square	F	Sig.
Jidoka Knowledge	Between Groups	0.000	1	0.000	0.000	1.000
	Within Groups	37.875	30	1.263		
	Total	37.875	31			
Jidoka Gain Scores	Between Groups	72.000	1	72.000	22.154	0.000
	Within Groups	97.500	30	3.250		
	Total	169.500	31			

Similarly, no significant differences were found between low and high background knowledge groups in learning pull concepts. Although the difference in gain scores between the two groups was significantly different (p = 0.006) (See Table 23).

Table 23: Summary of ANOVA results for pull knowledge and pull gain scores for low and high pull background knowledge groups

		Sum of Squares	df	Mean Square	F	Sig.
Pull Knowledge	Between Groups	2.269	1	2.269	1.095	0.305
	Within Groups	55.938	27	2.072		
	Total	58.207	28			
Pull Gain Scores	Between Groups	23.688	1	23.688	9.069	0.006
	Within Groups	70.519	27	2.612		
	Total	94.207	28			

Linear regression was used to test for a possible relationship between background knowledge and self-efficacy beliefs and knowledge of lean concepts (Jidoka and pull) and to answer the second research question. No significant relationships between participant background knowledge or self-efficacy beliefs and lean knowledge were found (see Tables 24 and 25).

Table 24: Linear regression model for self-efficacy beliefs and Jidoka background knowledge on Jidoka learning

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	7.691	0.652		11.790	0.000
Self-efficacy beliefs	0.186	0.425	0.083	0.439	0.664
Jidoka Background knowledge	-0.052	0.108	-0.092	-0.487	0.630

Table 25: Linear regression model for self-efficacy beliefs and Jidoka background knowledge on Jidoka learning

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	6.248	0.914		6.836	0.000
Self-efficacy beliefs	0.215	0.584	0.070	0.368	0.716
Pull background knowledge	0.216	0.184	0.224	1.173	0.251

5.7 **Conclusions and Future Research**

The purpose of this study was to investigate the influence of background knowledge on learning lean concepts (Jidoka and pull) and to examine the relationship between self-efficacy beliefs, background knowledge, and lean knowledge. One significant finding of this study was that most participants improved their lean knowledge after participating in the TimeWise role-playing simulation, as measured by the difference in Jidoka2 and Jidoka1 scores and by the difference in Pull2 and

Pull1 scores. The findings show that the role-playing simulation can be used as a good supplement to traditional teaching methods. It is also notable that the learning gains were higher for students with less background knowledge. These results provide evidence that the role-playing simulation “evened the playing field” and helped students improve their knowledge of lean concepts, regardless of the level of background knowledge. There were no significant relationships between background knowledge or self-efficacy beliefs and learning identified. The results did not support previous research in which individual self-efficacy beliefs was found to influence performance and learning achievement (Stevens, 1980; Pajares, 1996).

The course studied used both traditional teaching methods and nontraditional teaching methods. Students were taught lean principles and methods using traditional teaching methods first and then exposed to a lean role-playing simulation. Future research where traditional teaching methods and nontraditional teaching methods are used in separate course sections would be valuable. Additional research in which participant self-efficacy beliefs is measured both before and after students participate in role-playing simulation might also provide a better approach to understanding the role of self-efficacy beliefs on performance and learning achievement. Moreover, to increase the generalizability of the research findings the study should be replicated in other engineering programs.

5.8 **References**

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AN EXPLORATORY INVESTIGATION OF THE IMPACT OF COLLABORATIVE AND SIMULATION SESSIONS ON LEAN LEARNER PERCEPTIONS AND ACHIEVEMENT

Juthamas Choomlucksana and Toni L. Doolen

6. An Exploratory Investigation of the Impact of Collaborative and Simulation Sessions on Lean Learner Perceptions and Achievement

6.1 Abstract

6.1.1 Background

The use of collaborative and simulation sessions for lean training and education has been explored in organizations through various research studies. Some research has found these sessions to improve learning, but few studies have investigated the relationship of these sessions with other learning factors, e.g., self-efficacy beliefs and attitudes.

6.1.2 Purpose (Hypotheses)

A set of research questions were developed to address the effects of collaborative and simulation sessions on learning lean principles and methods and on self-efficacy beliefs and attitudes. The effects of background knowledge and relationships between learning and self-efficacy beliefs and attitudes were investigated.

6.1.3 Design/Method

Data for this study were collected during two offerings of a Lean Manufacturing Systems Engineering course at Oregon State University, run in two consecutive years (2010 and 2011). Surveys were distributed to participants eight

times during each ten-week term. The results were analyzed using paired t-tests, analysis of variance, and regression analysis.

6.1.4 Results

Findings indicated that participant learning differences exist for both lean methods after participating in collaborative sessions; whereas, participating in simulation sessions affected only learning related to Jidoka methods. Overall, participating in simulation sessions did affect participant intrinsic motivation, but only for Jidoka learning and only in Fall 2010. Type of sessions and background knowledge were found to have some impact on learning; whereas, self-efficacy beliefs had a significant effect on some attitudinal measures.

6.1.5 Conclusion

The findings confirm the benefits of the use of collaborative sessions for teaching lean principles and methods, when used for two different lean methods. The impact of collaborative and simulation sessions appear to be different depending on the lean concepts being taught. Background knowledge had a mixed effect on learning. It was found to impact intrinsic goal motivation.

6.1.6 Keywords

Lean, lean principles and methods, collaborative learning, simulations, games, self-efficacy beliefs, background knowledge.

6.2 **Introduction**

The term "lean manufacturing" or "lean" refers to a strategic improvement methodology. Lean systems use the fewest resources e.g., material, capital investment, inventory, floor space, operating time, and human effort, possible to produce the best product or service with the highest quality. Lean was first introduced in the 1960s at Toyota Motor Company in Japan. Toyota introduced self-monitored machines, organized machines in process sequence, and pioneered quick setups and changeovers (Womack, 2002). Overall, this approach came to be known as "Just-in-Time manufacturing" and the "Toyota Production System." In the 1990s, the approach became known worldwide when Womack, Jones, and Roos (1990) described the success of Japanese car manufacturers in the book, *The Machine that Changed the World*. Lean aims to eliminate non-value added activities and reduce costs, resulting in increased productivity and increased value for the customer. Studies reveal that non-value added activities (also called waste) can be found in all areas of manufacturing or business processes. Waste refers to any activity that does not add value to the process and to activities that a customer would be unwilling to pay for (George, 2002). Waste can be classified into seven categories: overproduction, unnecessary transportation, excess inventory, unnecessary motion, over processing, waiting, and defects. Taj (2005) indicated that approximately 70-90% of a company's available resources are applied to activities that do not add value.

Even though lean has been around for decades, lean is still considered to be an innovative strategy for improving the operating efficiency of a company or organization. Fleischer and Liker (1997) stated that organizations that have implemented lean realize huge benefits, from substantial cost savings to better quality, over organizations practicing traditional mass production. Moreover, many studies have observed the benefits of lean to manufacturing and, more recently, to service organizations when properly implemented. For example, Dickson et al. (2009) found lean was successfully implemented in an emergency department. During a year of lean implementation, the department saw improved patient flows and increased patient satisfaction without increased wait times. Similarly, Salem and Zimmer (2005) applied lean principles and methods to reduce processing time and to eliminate non-value adding activities in the construction industry with positive results. The use of the lean method, value stream mapping, helped employees in construction companies visualize waste, separate non-value added activities from value-added activities, and eliminate non-value added activities in three different structural steel erection processes.

Although studies have identified many organizations that were successful in implementing lean, other studies have found that many organizations have failed in the implementation of lean methods (Liker, 2004; Hamzeh, 2009). Given these findings, it is not surprising that many organizations are looking to hire individuals, who have the knowledge and skills needed to successfully implement lean methods. Pirraglia et al. (2009) investigated lean implementation processes in the wood industry. The study found that training and educating employees on lean principles and methods can result in a competitive advantage through substantial cost reductions. The principles and methods of lean have received attention from all over the world. As a result, the demand for workshops and training on lean has increased dramatically. Many forms of lean programs can be found. Online self-study methods, on-site training sessions and workshops are some of the approaches used to develop the skills and knowledge needed to understand lean principles and to apply lean methods.

According to a search of online jobs, there appears to be a need for specialty industrial or manufacturing engineering candidates who are familiar with lean principles and methods (Job Search Engine, 2011). Courses focusing on lean principles could be extremely valuable in helping to prepare engineers to apply lean knowledge in the workplace. For example, Taninecz (n.d.) and Fliedner (2007) contend that while lean principles and methods have been taught for more than decade, stand-alone lean courses are rare, and the majority of learners leave engineering programs with a minimal understanding of lean. In addition, when lean is taught, lean principles and methods are typically introduced to learners in the higher education classroom through traditional teaching methods (Thomas, 2008). Traditional teaching methods include assigned readings from textbooks, lectures, and/or case studies. The main learning structure in the traditional classroom is most often lectures. Moreover, traditional classroom environments are generally characterized as teacher-centered and consist of limited teacher-student and student-student interaction and minimal engagement in tasks (Boe & Shin, 2005). Although traditional classroom environments are effective in delivering content for most courses, learners of lean principles often have difficulty understanding how to apply lean principles without practice (Balle, 2005).

Over the past decade, studies have reported on the trend towards increasing the use of non-traditional teaching methods such as collaborative activities and simulation activities, in the workplace and as a support tool for teaching in either industrial and academic settings. For example, some universities e.g., Massachusetts Institute of Technology, Ohio University, University of Kentucky, and others have developed and used simulations to teach and train staff about lean principles and methods. Similarly, Verma (2003) reported that at least 17 simulations have been used as a part of lean manufacturing training programs. Many researchers have found strong evidence that non-traditional teaching methods can be valuable in teaching and training. In response to researchers' successful tests and trials of role-play and simulations and/or games, many educators have developed and applied learning simulation activities to courses, including the TimeWise Simulation (Worcester Polytechnic; University of Pittsburgh Northeastern University, 2008), the Lean Enterprise Value Aircraft (McManus et al, 2007), and the Pipe Factory Simulation at University of Dayton (Verma, 2003).

Although lean simulations have had a positive impact on learners and practitioners, the impact of these simulations and games has not been fully investigated. Lean trainers and educators need to find ways to assess learner performance and outcomes. The results of such findings may help educators and researchers make more informed decisions in preparing lean courses. To investigate and understand how the use of non-traditional teaching methods effect teaching and training on lean principles and methods, this study examined whether the use of lean collaborative activities and a widely adopted, role-playing simulation (called the

TimeWise) improved learning, self-efficacy beliefs, and attitudes. Relevant background information and related literature are summarized next.

6.3 Background and Related Literature

6.3.1 Lean Manufacturing

Cost reduction, shorter lead-time or cycle time, and maintenance of higher quality are major considerations for success in companies, especially during an economic downturn. Lean manufacturing is one of many strategic improvement methodologies that has been used worldwide. Lean manufacturing, also known as lean, is a continuous improvement methodology that refers to using the fewest resources e.g., material, capital investment, inventory, floor space, operating time, and human effort, possible to produce the best product or service with the highest quality. Lean was first introduced in the 1960s at Toyota Motor Company in Japan, by the Toyota executive, Taiichi Ohno. The earliest roots of lean can be traced back to the work of industrialist Henry Ford in the early 1990s. Taiichi Ohno and his colleague, Shingo Shigeo, were interested in Ford's production line for the assembly of the Model T automobile. The production system for the Model T automobile was a major innovation, which was focused on high volume production at low cost. Taiichi Ohno and Shingo Shigeo developed a new concept in response to elements of the system that were not applicable to the Japanese market in the 1960's. This adapted production system later became known as the Toyota Production System and later as lean.

Although lean was first developed for manufacturing purposes, many studies have documented benefits of successfully applying lean principles and methods in service organizations, e.g., healthcare, customer service, government offices, and even financial service companies. Lean aims to continuously eliminate non-value added activities in manufacturing and business processes, while maximizing customer value resulting in increased productivity and a competitive advantage. Non-value added activities, called waste or muda in Japanese, refer to any activities that do not add value to the process or product and that a customer would be unwilling to pay for (George, 2002). Examples of waste include an unnecessary process step, poorly selected equipment, and duplicate paperwork. Waste can be classified into seven categories: overproduction, unnecessary transportation, inventory, unnecessary motion, over processing, waiting time, and defects. According to Taj (2005), approximately 70-90% of companies available resources are applied to activities that do not add value to the process or product. Efforts toward waste elimination through the application of lean methods can increase a company's production efficiency, reduce cycle times, and lower costs.

The benefits of a lean transformation have been documented in many studies, both in and out of manufacturing (Lean Enterprise Institute, 2003; Wysocki, 2004, Womack & Jones, 2005). For example, Wojtys et al. (2009) showed that lean techniques could be used with considerable success to improve the patient scheduling process in an outpatient sports medicine clinic. Value stream mapping (VSM) was the main lean tool used to evaluate the existing flow of information in the patient scheduling system and to identify and eliminate waste during the patient scheduling process. The results indicated that some patients spent up to 36 days and required up to 21 phone calls to schedule an appointment. Typically, only 10% of all steps in a process actually added value in the process (Wojtys et al., 2009). After 14 months of applying lean tools, approximately 76% of patients were scheduled with only one call, averaging 2.5 minutes per call. The study also found an overall positive impact on hospital service quality ratings based on information provided in a self-reported patient satisfaction questionnaire two months after the lean implementation. Similarly, L'Hommedieu and Kappeler (2010) demonstrated that VSM helped identify waste, unnecessary processing, and overproduction in pharmacy operations, especially in medication preparation and dispensing. VSM was used to generate ideas for improvement. The results showed that wasted doses were reduced from 16.6% of the total doses dispensed to 8.6%. The use of VSM helped the hospital achieve savings of over $400,000 annually.

Lean is an improvement methodology that focuses on identifying and eliminating waste through continuous improvement. Learning and training in lean require training in both soft and hard skills related to solving social or cultural and technical problems in the production system (Badurdeen, Marksberry, Hall, & Gregory, 2010). To this end, more and more lean courses, expert training, and coaching models for workers have been developed, many of which rely on non-traditional teaching methods.

6.3.2 **Non-traditional Teaching Methods For Lean Training and Teaching**

Collaborative activities, simulations, and games are the most commonly used approaches to engage learners. Previous researchers have found that collaborative activities and simulation have created successful results in groups of all ages. Collaborative activities and simulation activities are different from activities associated with traditional teaching methods. Brakley et al. (2005) defined collaborative learning as learning where two or more learners work together toward the achievement of a shared learning goal. Chang and Chen (2008) described collaborative activities as interactive activities among learners where an exchange of knowledge occurs and cooperation is required to complete specific tasks.

On the other hand, simulation activities are defined as activities that attempt to mimic or simulate real-life situations or environments. Simulations and games are distinct from each other. The difference between games and simulation is that games have a winner and loser, while simulation provides the learner or player with an opportunity to experience a situation that is close to a real-life situation. Bredemeier, and Greenblat (1981) defined simulations as “a hybrid from of game-based performance activities in simulated contexts.” Simulations, when used for teaching and/or training, give learners opportunities to participate in activities that are close to real-life experiences. Simulation and/or games can include role-playing techniques if a learner, also called player, is expected to think and act as a person in a defined and/or given role. Role-playing technique consists of three major steps (Alden, 1999). First, learners are introduced to the purpose of the session. If the style of the role-playing requires learners or players to act in the role, learners are told about the situation and setting for the role-play. Second, the role-play is run. Last, a discussion session is conducted at the conclusion of the role-play. Many role-play simulation activities allow learners or players a chance to be involved. This approach allows the learners or players to apply knowledge in imaginary or real world situations during the simulation runs (Sutcliffe, 2002).

Although collaborative and simulation sessions have been shown to play an important role in participant learning in some studies, other studies have found that these types of learning activities do not improve learning. For example, Overlock (1994) compared learning outcomes in physics classrooms after both traditional and collaborative techniques were applied. Results showed that there were no statistically significant differences in the final exam scores of the two groups. Similarly, Krain and Lantis (2006) indicated that there is little to no significant relationship between the use of and/or simulations and individual learning outcomes. Badurdeen, Marksberry, Hall, and Gregory (2009) stated common drawbacks in some existing lean simulations. The researchers identified a "lack of stress on soft skills, a mistaken focus on 'linear lean,' misunderstanding of the key role of the facilitator, and lack of realism (p.1)."

Given these conflicting findings, an understanding of how collaborative and simulation sessions affect participant learning is needed, so that trainers and educators can maximize the educational benefits. Although some studies have found that collaborative activities and simulation activities can play an important role in providing learners with a better understanding of the principles and methods of lean, additional research is needed. Some of the important variables related to learning, including background knowledge, self-efficacy beliefs, and attitudes are discussed next.

6.3.3 **Background Knowledge**

In prior research, learner background knowledge was found to exert a significant influence on learning outcomes (Steven, 1980; DePaolo & McLaren, 2006). The term "background knowledge" is often used interchangeably with existing content knowledge and prior knowledge. Background knowledge can be defined in many different ways. For example, Stevens (1980) defined background knowledge as "…what one already knows about subject…" (p.151). Biemans et al. (2001) described background knowledge as "…all knowledge learners have when entering a learning environment that is potentially relevant for acquiring new knowledge…."

Examples of the impact of varying background knowledge on performance, behavior, and/or achievements do exist. Stevens (1980) studied the role of background knowledge on 108 ninth grade students English reading performance. Three tests including knowledge, comprehension, and reading were distributed during the regular period. Results of the study support previous work that links background knowledge and learning outcome achievement. The researchers found that background on the topics being read led to improved reading performance. Tobias (1994) found a linear relationship between background knowledge and interest in learning. Hailikari and

Nevgi (2010) studied the relationship between student background knowledge and achievement in an introductory chemistry course. The background knowledge questionnaire was distributed to students during the first lecture without notification about the test. Four areas of background knowledge were investigated: the knowledge of facts, knowledge of meaning, integration of knowledge, and application of knowledge. Student achievements were measured using the date that students passed the final exam and final grades. The results of the study showed that students who had a deeper level of background knowledge were more likely to complete the course within a scheduled time frame and with higher final grades. Other students with lower levels of background knowledge dropped out or did not complete the course within the scheduled time. Similarly, DePaolo and McLaren (2006) found a positive relationship between student background knowledge and learning in business statistics and calculus. The research results revealed that students with no background knowledge in calculus had negative attitudes and poor exam performance.

6.3.4 **Self-efficacy Beliefs**

Similar to research on background knowledge, many studies have demonstrated a connection between self-efficacy beliefs and participant performance including computer technology use (Isman & Celikli, 2009; Chu & Tsai., 2009), educational achievement (Adeyemo, 2007; Wang & Wu, 2008), and work performance (Betz & Hackett, 1987; Machida & Schaubroeck, 2011).

Self-efficacy beliefs can be described in various ways. The concept of self-efficacy beliefs was first introduced by Bandura in 1997. Bandura defined self-efficacy beliefs as “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments, p.3.” Seifert (2004) has defined self-efficacy beliefs as “a construct synonymous with confidence and refers to a person’s judgment about his/her capability to perform a task at a specified level of performance, p.137.” Self-efficacy beliefs reflect people’s belief about whether “they can” or “they cannot” commit to a specific task. Moreover, people who have a high level of self-efficacy beliefs believe they can do or complete a task. People with high levels of self-efficacy beliefs have been shown to work harder and show more persistence, leading to greater success, compared to those who have lower levels of self-efficacy beliefs. Those with lower self-efficacy feel they cannot do or complete a task and, as a result, try to avoid the task. Siegle (2000) found the level of self-efficacy beliefs to impact the level of effort and amount of time required when confronting a task and/or obstacle. Bandura stated that people learn not only through experiences but also from observing others perform and by observing outcomes. Bandura pointed out four major experience sources that can influence individual self-efficacy beliefs. The four main sources are mastery experience, vicarious experience, verbal or social persuasion, and physiological factors. One way in which to help people develop higher self-efficacy beliefs is through the concept of mastery experience. Mastery experience refers to the performance success or failure associated with an individual’s previous task experiences. For example, success on a midterm exam can lead to an increased level of self-efficacy beliefs for the next test; whereas, failure on a midterm exam can lower levels of self-efficacy. People can apply this principle to help experience incremental success, resulting in an increase in self-efficacy. Vicarious experience refers to observing others' experiences or performance with success or failure in a similar or situation task. For example, one's level of self-efficacy beliefs can increase by seeing others successfully accomplish a task. Social persuasion refers to the belief that the level of self-efficacy beliefs may increase or decrease depending on judgment, feedback, and support received from others. Lastly, physiological reaction refers to the belief that the level of self-efficacy may increase or decrease based on physiological factors e.g., moods, emotions, states, physical reactions, and stress.

Similar to research on background knowledge, many studies have demonstrated a connection between self-efficacy beliefs and participant performance. Some have found relationships between self-efficacy beliefs and computer technology use (Isman & Celikli, 2009); whereas, others have found self-efficacy beliefs to influence educational achievement (Adeyemo, 2007; Linnenbrink & Pintrich, 2002; Yildirim, n.d.) and work performance (Betz & Hackett, 1987; Machida & Schaubroeck, 2011). Isman and Celikli studied participant self-efficacy beliefs related to computer technology. Findings showed that there is a significant relationship between the level of self-efficacy beliefs and computer skills.

Likewise, Adeyemo (2007) studied the moderating influence of emotional intelligence on academic self-efficacy beliefs and achievement among university students. The results showed a significant relationship between emotional intelligence and self-efficacy beliefs and academic achievement. Linnenbrink and Pintrich (2002) studied the relationship of academic self-efficacy beliefs, attribution, intrinsic motivation, and achievement. The results demonstrated that academic self-efficacy beliefs play a positive role on academic learning outcomes and behavior. Linnenbrink and Pintrich (2002) suggested that schools should create and develop positive self-efficacy beliefs in students as way of improving student learning and achievement. As previously described, self-efficacy beliefs have been found to be related to learning, behavior, and performance.

6.3.5 **Attitudes**

Many studies have found attitudes to be an important factor in understanding and predicting people's reactions to events or changes in behavior (Fishbein & Ajzen, 1975). A strong correlation between individual attitudes and learning outcomes has been identified in previous research. For example, Luckie et al. (2004) argued that a significant and positive improvement in attitudes towards the learning experience might lead to higher learning achievement. According to Bartley's (1970) study on foreign language learning, there was a positive relationship between individual attitudes and foreign language learning outcomes, such that students who dropped out of their foreign language class had foreign language attitude scores that were lower than the attitude scores of those students who remained in the class. Bartley concluded that individual attitudes are the most important factor in academic success. Depaola and Mclaren (2006) investigated the relationship between undergraduate business student attitudes and performance in learning statistics and calculus. These results supported previous research in which there were significant relationships between learner attitudes and learning outcomes. The study results also indicated that learners who earned lower exam scores showed negative attitudes toward statistics and calculus. Depaola and Mclaren argued that learners who did not have a background in calculus did poorly on the exam and held strong negative attitudes toward calculus.

The term "attitudes" can vary widely in how it is defined. There are also many different types of learner attitudes to consider. For example, Gardner (1985) defined an individual's attitude as "an evaluative reaction to some referent, inferred on the basis of the individual's beliefs or opinions about the referent, p. 9." Rajamanickam (2005) described attitudes as "positive or negative responsive tendency of a person towards a person, object, or situation, pp. 822-823." Some attitudes relevant to learning are motivation and enjoyment.

Mullins (1996) defined motivation as "the driving force within individuals by which they attempt to achieve some goal in order to fulfill some need or expectation, p.184." Motivation can be further described by three constructs: intrinsic goal orientation, extrinsic goal orientation, and task value. Intrinsic goal orientation refers to the degree to which one perceives his/herself to be participating in a task because the task itself is perceived as challenging and arouses curiosity. Extrinsic goal orientation refers to degree to which one perceives his/herself to be participating in a task because the task itself is connected with a desired external motivator, e.g., a high course grade, a reward, or a course credit. Task value refers to degree to which one perceives his/herself to be participating in a task because the task itself is perceived as important. Motivation has been found to play an important role in learning outcome achievement (Lin et al. 2001; Eccles et al. 1983; Eccles, 2005).

Enjoyment can be defined as the degree of positive feelings resulting from an experience. Although some studies have found a positive relationship between learner enjoyment and outcomes (Blunsdon et al., 2003), other studies have not found a link between these two (Rieber & Nach, 2008). As a result, there are still many questions to be answered about the effect of learner enjoyment on learning and performance. The results from previous studies on lean, teaching lean, and the role of background knowledge, self-efficacy beliefs, and attitudes on learning were used as the basis for developing the research questions for this study.

6.4 **Purpose of Study and Research Questions**

The purpose of this study was to investigate the influence of collaborative and simulation sessions on learning lean principles and methods. This investigation was aimed at understanding how to train and teach lean principles and methods effectively so that learners can readily translate learning to application in the workplace. Background knowledge, self-efficacy beliefs, and attitudes, before and after participating in collaborative activities and simulation activities, were studied. Nine research questions guided the design of this study.

1. Do learners demonstrate improved levels of lean knowledge after participating in collaborative sessions?
2. Do learners demonstrate improved levels of lean knowledge after participating in simulation sessions?

3. Does the type of session affect learning?
4. Do learner self-efficacy beliefs increase after participating in simulation sessions?
5. Do learner attitudes improve after participating in simulation sessions?
6. Does the level of background knowledge have an impact on learning lean?
7. Does the level of background knowledge have an impact on learner attitudes?
8. Is there a relationship between the type of session, self-efficacy beliefs, background knowledge, and learning?
9. Is there a relationship between the type of session, self-efficacy beliefs, background knowledge, and learner attitudes?

6.5 **Methodology**

6.5.1 **Participants**

All participants in this study were undergraduate and graduate students who enrolled in a lean course, called Lean Manufacturing System Engineering, at Oregon State University. A group of 32 students participated during Fall 2010 and 38 students during Fall 2011. The majority of undergraduate students were upper division students (junior or senior year). Both undergraduate and graduate students were primarily from three different engineering majors: Industrial Engineering, Manufacturing Engineering, and Mechanical Engineering.

6.5.2 **Details of Lean Manufacturing Systems Engineering Course**

The outcomes of the course as described in the syllabus were 1) Describe, in writing, lean manufacturing principles and the appropriate lean manufacturing practices to apply in response to specific problems posed in case studies, homework problems, and exams; 2) Identify and describe the relevance of lean manufacturing principles and practices in the enterprise to manufacturing processes and equipment, supply chain management, product development, and human resource management; 3) Plan, implement and evaluate the impact of lean manufacturing principles and practices in a simulated manufacturing setting. The course was ten weeks in length. The course consisted of approximately three hours of lectures and in-class activities and two hours of simulations each week. Two types of learning sessions were used: collaborative and simulation sessions. Collaborative sessions consisted of lectures and in-class activities. Lectures consisted of the instructor presenting a variety of text-based materials using PowerPoint presentations. In-class activities incorporated discussion questions, hands-on activities/exercises, and/or in-class exercises in which learners were able to apply acquired knowledge to presented problems within a short period. In short, in collaborative sessions, learners were asked to work together as a group or team after lectures.

In this study, two collaborative activities were studied. The first collaborative activity, called the nightlight manufacturing activity, was focused on poka-yoke device design. The second collaborative activity, called the paper airplane activity, was focused on the differences between push and pull productions systems. The nightlight manufacturing activity with poke-yoke device design was used at the end of Jidoka lectures as a practice Jidoka activity. This activity was completed in about 30 minutes. Four to five learners work together to describe and sketch at least three different poka-yoke devices, including control, warning, and setting poka-yoke devices that can be used to prevent mistakes in the assembly of a simple nighlight.

Learners disassemble a nightlight first to understand the construction of the product. The goal of the activity is to provide a realistic scenario for learners to apply mistake-proofing methods to a simple set of operations.

The second activity was used at the end of a series of lectures on pull production. This activity was completed in about 30 minutes. A total of five learners work together in a paper airplane factory. Each factory includes four assembly workers and one quality assurance worker. An example of a workstation setup for the activity is shown in Figure 12. Three iterations of the activity are run. In the first iteration, learners start working using standard push manufacturing techniques. In this round, learners are able to produce batches of six paper airplanes at workstations without worrying about inventory. In contrast, the manufacturing is changed from batches of six to batches of three planes during the second iteration. In the third iteration, a pull system is used. Planes are made one at a time and strict rules of pull production must be followed. The goal of this activity is to illustrate the difference between pull and push methods in an operational setting in a way that is both fun and instructional.

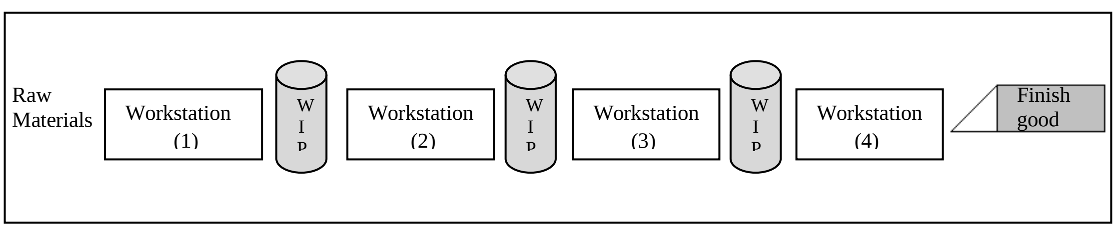


Figure 12: Paper airplane production line setup

In addition to using collaborative learning activities, the course included a weekly laboratory. In the weekly laboratory, a simulation was used. TimeWise simulation was the simulation used for this course. Simulation sessions were conducted in separately scheduled laboratory sessions. The length for each simulation session was approximately two hours. The TimeWise simulation is usually played in four rounds. Each round takes approximately 15 minutes to complete and is followed by a short group discussion. Participants work as a group to assemble two clocks; a blue clock and a black clock. Each participant plays a different role in the clock factory such as assembly operator, production planner, material handler, warehouse clerk, or inspector. Moreover, each learner is assigned to a smaller team of learners that work together as a consultant for the TimeWise Company. Each team is required to complete a report to present four recommendations to improve the TimeWise Company. As a result, learners are able to learn lean in action in the simulated clock factory and are also given the opportunity to analyze the impact of lean activities in their role as a consultant.

Participants experience traditional manufacturing in the first round and learn to apply lean manufacturing principles and methods during the second, third, and fourth rounds. The number of positions/workstations in the TimeWise assembly line are adjusted for each round. In the TimeWise simulation, each participant is assigned to play a different role/task as a member of the TimeWise Company each round. Participants can also be asked to change job positions during a simulation run. Each round typically consists of two to four simulation runs.

The TimeWise factory includes three different functional areas, suppliers (e.g., suppliers, quadrant vendor, hand vendor), manufacturing (e.g., material handler, face assembly, back assembly, clock assembly, hand assembly, kitter, inspection and rework), and support (e.g., supervisor and industrial engineer) or front office (e.g., design engineer, sales representative, application engineer). Several lean principles and methods are applied in each round, including pull production, poka-yoke, 5S, and visual workplace techniques. A sample TimeWise layout is shown in Figure 13.

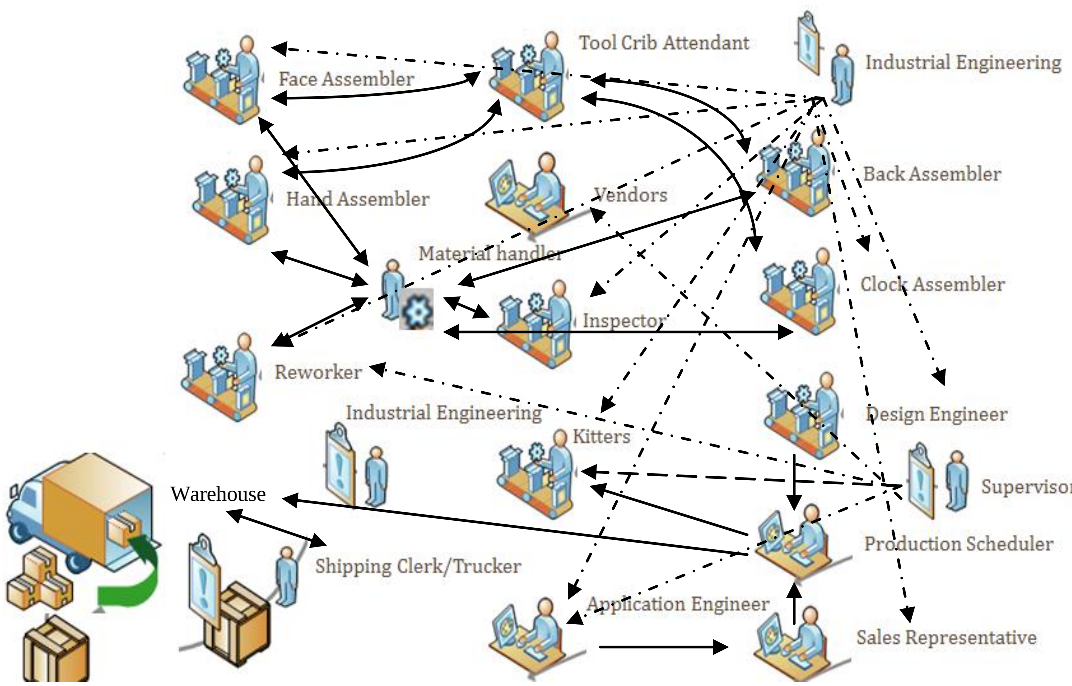


Figure 13: Sample of TimeWise simulation layout (First Round)

6.5.3 **Instruments**

Eight surveys were developed and used in this study. Surveys were distributed to participants at various points during the ten-week quarter in both Fall 2010 and 2011. The surveys included six different learning surveys, some with self-efficacy belief items and two attitude surveys. The self-efficacy beliefs surveys were administrated at the end of collaborative and simulation sessions for each lean method. The first two surveys for each lean method were used to measure participant knowledge before lectures and collaborative sessions. Four surveys were used to measure participant learning and self-efficacy beliefs for the two different types of sessions. Two additional surveys were used to measure participant attitudes. The surveys will be referred to as Jidoka1, Jidoka2, Jidoka3, Pull1, Pull2, Pull3, Attitude-Collaborative, and Attitude-Simulation. Each survey is described further next.

Jidoka1 and Pull1 each consisted of ten multiple-choice questions designed to measure content knowledge on these two lean methods: Jidoka and pull. Each question had four possible choices as answers. Jidoka2, Jidoka3, Pull2, and Pull3 each consisted of ten multiple-choice questions and six Likert scale items that were designed to measure learning and self-efficacy beliefs. Attitude-Collaborative and Attitude-Simulation each consisted of 16 items that were designed to measure learner attitudes. All surveys are described in more detail next.

Learning Survey Development: In this research study, learning was measured using two sets of multiple-choice questions focused on two lean methods. These two methods were Jidoka and pull. These two lean methods were selected as representative examples of lean techniques and used to assess participant learning resulting from a particular type of session (collaborative or simulation). The series of content questions were developed by the researcher and reviewed by the course instructor.

The surveys were administrated three times, once before any lectures and collaborative sessions, after collaborative sessions, and again after simulation sessions. Sixty different multiple-choice questions were created to measure content knowledge. Four answer choices per questions were provided. Each survey contained a total of ten multiple-choice questions. The questions developed were of moderate difficulty and were designed to measure aspects of these methods covered in the course curriculum. Some examples of the content questions included on these surveys are provided in Table 26.

Table 26: Example content knowledge questions

Lean Method	Example Question
Jidoka	At the end of submitting a purchase order, a customer will be worried if the provided zip code does not match the customer's address. This is an example of which of the following techniques? a. Poka-Yoke. b. Jidoka. c. Andon. d. Muda.
Jidoka	If a plant manager requires that each operation inspects the work of the previous operation. Which of the following may occur? a. Discovers defects. b.Reduces defects. c. Eliminates defects. d. All of the above.
Jidoka	A sensor alarm at the Valley Library gate is an example of which one of the following types of Poka-Yoke? a. Administration Poka-Yoke. b.Warning Poka-Yoke. c. Control Poka-Yoke. d. Setting Poka-Yoke.
Pull	Which of the following types of Kanban card is used to signal when a machine has broken down? a. A conveyance Kanban. b. A production Kanban. c. A delivery Kanban. d. None of the above.
Pull	Which one of the following is an example of a push system? a. Snack vending machines. b. Supermarket shelves. c. Laptop customization at Dell. d. None of the above.

Jidoka was first introduced by Shigeo Shingo in the early 1900's. Jidoka is a lean method used to prevent and detect production defects. Jidoka is also known as "automation" and "quality at the source." The term "automation" can be described as simulated human intelligence (Khalil, Khan, & Mahmood-Student, 2006). The basic idea behind Jidoka is to detect and correct problems. The purpose of Jidoka is to empower workers to take control before a problem occurs or to stop work when a problem or something unexpected occurs (Black, 2008). Andon and Poka-yoke are common tools used in Jidoka to visually control quality and to prevent defects. Many things can go wrong in a manufacturing environment to cause problems (abnormalities and defects). The methods of Jidoka have helped organizations reduce and eliminate waste, such as over processing, over production and defects.

Pull production is sometimes referred to a “just-in-time production” (JIT) in which planning and scheduling of production is based on customer demand. Traditional manufacturing systems typically use push production processes, i.e. the production of products or services is based on forecasts rather than actual demand. A successful implementation of pull production can help companies earn more and waste less through increased workflow speed, reduced inventory levels, reduced lead times, and eliminated scheduling complexities. The topic of pull production was chosen to be included as a representative method because pull production has been shown to positively impact the efficiency of a production system and also because the transformation from a traditional manufacturer to a lean manufacturer often is initiated by the implementation of pull production methods.

Self-efficacy Beliefs Survey Development: Self-efficacy beliefs surveys were used to assess learner confidence in the ability to perform and apply lean knowledge as a result of a particular type of session. Self-efficacy beliefs were measured using a modified version of a survey used in previous research. The previously developed survey is called the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al, 1993). Pintrich et al. (1993) developed survey items to evaluate individual participants according to interest, importance, utility and challenge, curiosity and mastery. The MSLQ items have been successfully used by many researchers, e.g. Mullen et al. (2006) and Berg (2007). The internal reliability of the

MSLQ items have been reported in previous studies, and Cronbach alpha coefficients ranged from 0.62 to 0.93. The self-efficacy beliefs survey used in this research study consisted of six items (see Table 27). The self-efficacy beliefs survey items were modified to specify a type of session: collaborative or simulation. The self-efficacy beliefs survey items were included in four surveys: Jidoka2, Jidoka3, Pull2, and Pull3. A 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree) was used for all self-efficacy beliefs survey items.

Table 27: Survey items used to measure self-efficacy beliefs

Survey variables	Item Content
Self-efficacy beliefs	• As a result of [type of session]*, I believe that I will be able to respond to exam questions on lean manufacturing. • The [type of session]* increased my confidence in my own understanding of lean manufacturing principles. • I am certain I understand the most difficult principles used in the [type of session] today. • As a result of today's [type of session]*, I have no doubt about my capability to do well on lean manufacturing assignments. • As a result of today's [type of session]*, I can now explain to my friends what I have learned about lean manufacturing. • I am certain I can master the skills being taught in the [type of session]* today.

Note: the phrase, "type of session," was replaced with a particular type of session e.g.: collaborative or simulation session.

Attitude Survey Development: Attitude survey items were developed to assess how learners felt, thought, and reacted as a result of a particular type of session. Two different attitudes were measured: motivation and enjoyment. Items from the MSLQ, also used in developing self-efficacy beliefs items, were modified to assess motivation. The three constructs related to motivation that were identified in the literature were used: intrinsic goal orientation, extrinsic goal orientation, and task value. The motivation section of the survey consisted of twelve items, with four items for each of the three motivation constructs (see Table 28). The survey used to measure enjoyment was developed on the basis of previous research conducted by Berg (2003) and Pekrun et al. (2002). In this research study, enjoyment was defined as the degree to which a participant perceived his/herself to be participating or performing a task because the task itself was fun and/or enjoyable. The enjoyment construct consisted of four items (see Table 28). Both enjoyment and motivation survey items were combined and distributed to participants at the same time. Participants responded to survey items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree).

Table 28: Survey items used to measure motivation and enjoyment constructs

Survey Variable	Item Content
Intrinsic goal orientation	• I prefer [type of session] that are challenging so I can learn new things. • I prefer [type of session] that arouses my curiosity, even if they are difficult. • I prefer [type of session] that I will learn something from even if they require more work. • I prefer [type of session] that I can learn something from even if they do not guarantee a good grade.
Extrinsic goal orientation	• Learning from [type of session] helps prepare me for tests. • Learning from [type of session] helps me get a good grade on tests. • I participate in [type of session] because I am supposed to. • I prefer [type of session] because I am sure I can do them.
Task value	• As a result of [type of session], I believe that I will able to use what I have learned in other courses. • It is important for me to learn what is taught in [type of session]. • I think that what I have learned from [type of session] is useful for me to know. • As a result of [type of session], I believe that I can apply what I have learned to real-world problems.
Enjoyment	• I enjoy participating in [type of session]. • I feel that time flies when I participate in [type of session]. • After finishing [type of session], I look forward to the next class. • I would like to spend more time on [type of session session].

Note: the phrase, “type of session,” was replaced with a particular type of session e.g.: collaborative or simulation session.

6.5.4 **Data Collection Processes**

As the research involved human participants, data collection began only after obtaining approval from the Oregon State University Institutional Review Board. All data collection was completed during sessions (collaborative or simulation) during the

Fall of 2010 or the Fall of 2011. Students were given a brief overview of the research purpose, risks, and alternatives to participation in order to decide whether or not to participate in the study. A cover letter that explained the research purpose and instructions for participation were distributed to all participants.

Surveys were distributed to participants at various times throughout the ten-week terms in either Fall 2010 or Fall 2011. The term started in September and ended in December. Participants were told to write the last four digits of their OSU identification number (ID) on each survey. This information was used to match surveys from the beginning to the end of the study. Figure 14 summarizes the overall schedule for survey distribution during the ten-week term.

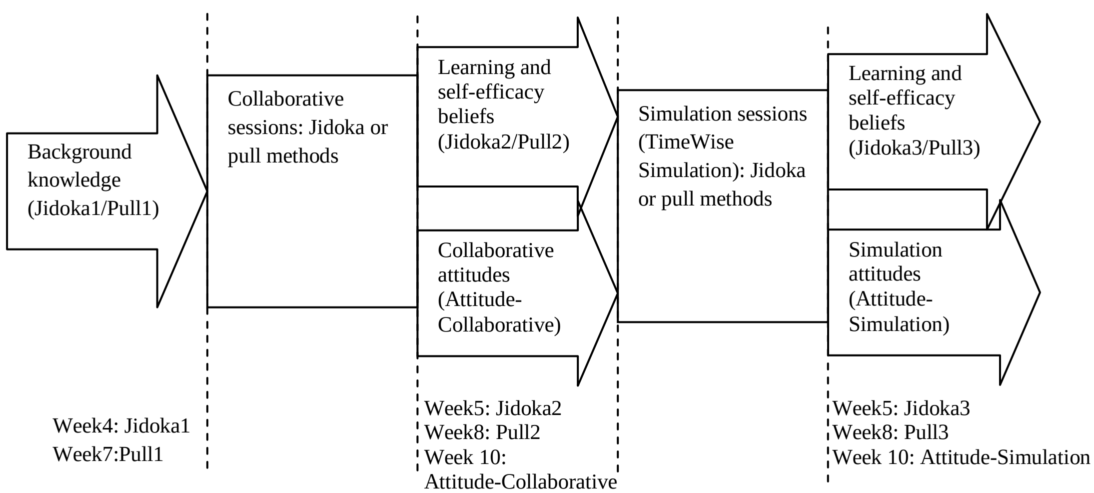


Figure 14: Timing for survey distribution

The timing for survey distribution was the same for 2010 and 2011. As seen in Figure 14, the surveys were distributed at several different times during the course. Jidoka1 and Pull1 were distributed to participants before any collaborative sessions or simulation sessions on Jidoka and pull methods were conducted. Jidoka2 and Pull2 were distributed to participants after a collaborative session, but before any simulation sessions on Jidoka or pull methods. Jidoka3 and Pull3 were distributed to participants after simulation sessions on Jidoka or pull methods were conducted. Attitude-Collaborative and Attitude-Simulation were distributed to participants after collaborative sessions and simulation sessions, respectively.

6.6 **Results**

Data were analyzed using SPSS (Version 19.0) and Microsoft Excel 2010. The Cronbach's alpha coefficients for intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment were 0.810, 0.615, 0.513, and 0.821, respectively. A Cronbach's alpha coefficient of 0.7 or more is considered satisfactory by some authorities, e.g. Nunnally (2010) and Garson (1978). While a Cronbach's alpha coefficient of 0.5 or above is considered acceptable by Bowling (1997). Prior to completing analyses of data, Q-Q plots were created and reviewed to determine whether or not the data were normally distributed. Representative Q-Q plots for data used for this study are shown in Figure 15. Descriptive statistics and parametric tests (e.g. paired t-tests, ANOVA, linear regression) were used to evaluate the different research questions. A p-value of 0.05 was used to identify statistically significant relationships.

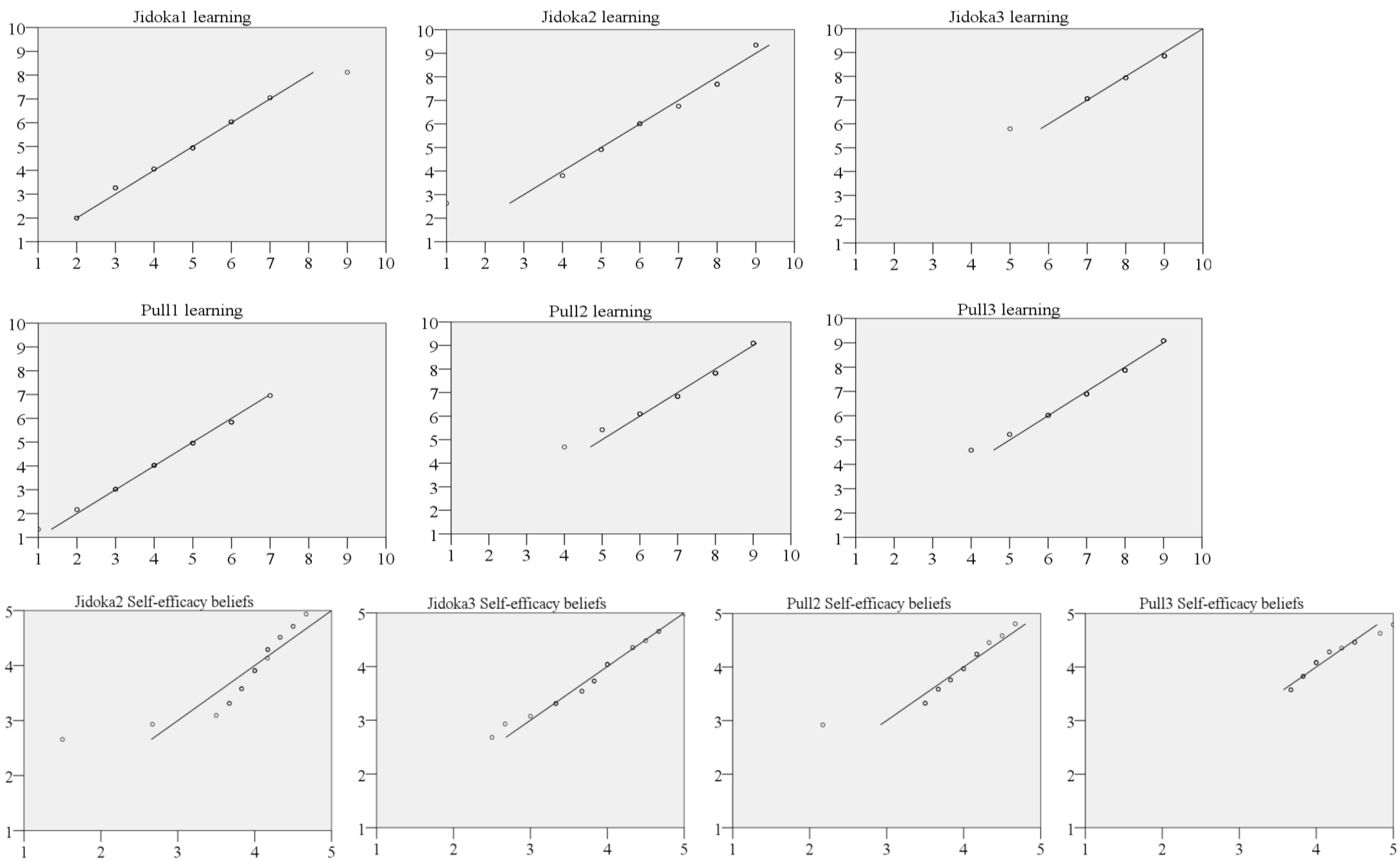


Figure 15: Representative Q-Q plots for each content knowledge and self-efficacy beliefs variable

The Q-Q plots were analyzed separately for each year (2010 or 2011). The data were observed to be approximately normal distributed. Analysis of variance (ANOVA) was used to test for difference between the scores for surveys administered in the Fall 2010 and the surveys administered in the Fall 2011. The ANOVA results showed that there were statistically significant differences in survey scores between Fall 2010 and Fall 2011. As a result, the data sets were analyzed separately. In the following sections, the research results for each research question are presented.

6.6.1 **Learning**

To measure the effects of the use of collaborative and simulation sessions on learning lean principles and methods, two lean knowledge surveys were administered. A total of six surveys (Jidoka1, Jidoka2, Jidoka3, Pull1, Pull2, and Pull3) with ten questions each were used to examine participant learning in two lean methods: Jidoka and pull. The first research question asked if learners demonstrate improved levels of lean knowledge on two lean methods (Jidoka and pull) after participating in collaborative sessions. Paired t-tests were conducted to compare test scores before and after participating in collaborative sessions on both Jidoka and pull methods. Table 29 and Figure 16 summarize the mean test scores, paired t-tests analysis, and box plot of these results for each year.

Table 29: Mean scores and paired t-test analysis results for learning based on test scores before and after participating in collaborative sessions.

Year	Survey	n*	Mean		P-value
			Mean scores	Paired t-test statistic	
2010	Jidoka1	23	4.65	-1.79	**0.002**
	Jidoka2	23	6.44		
	Pull1	30	4.33	-3.00	**0.000**
	Pull2	30	7.33		
2011	Jidoka1	25	5.36	-1.44	**0.003**
	Jidoka2	25	6.80		
	Pull1	38	5.32	-1.81	**0.000**
	Pull2	38	7.13		

*The number of participants varies based on the number of returned surveys that could be matched

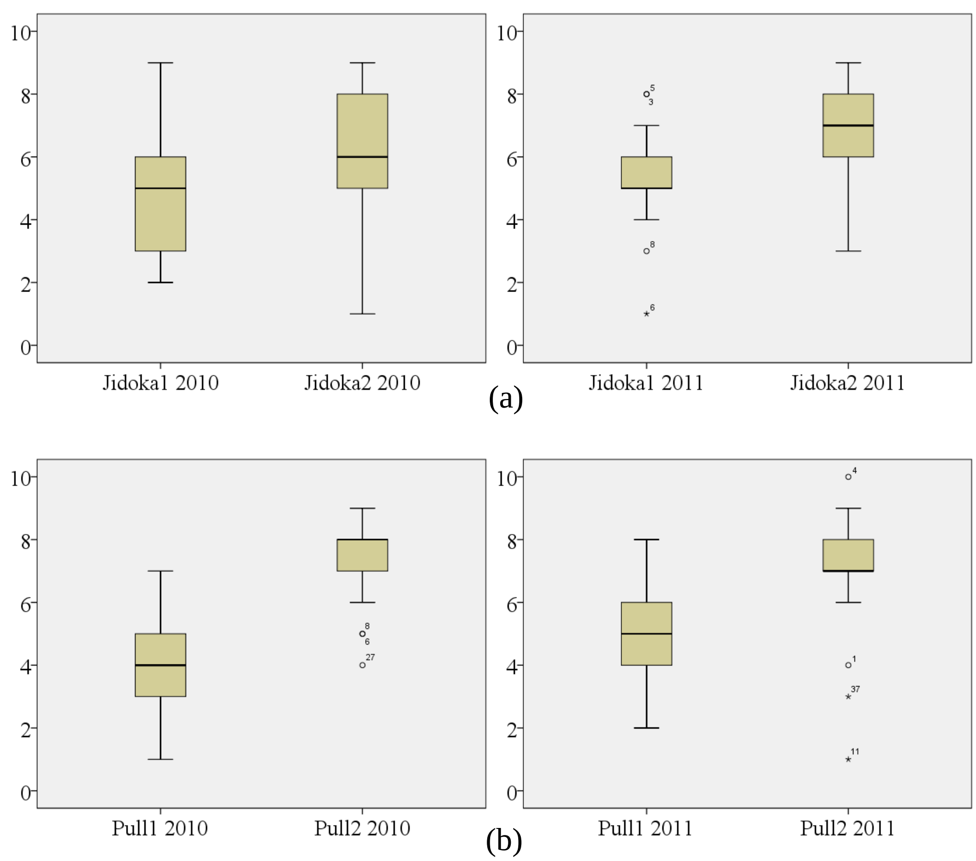


Figure 16: Box plots comparing (a) Jidoka1 and Jidoka2 during 2010 and 2011 (b) pull1 and pull2 during 2010 and 2011

Paired t-tests comparing Jidoka2 and Jidoka1 and Pull2 and Pull1 revealed a significant difference in mean scores in 2010 and in 2011 ($p < 0.05$). Learners showed knowledge gains after participating in collaborative sessions. The mean scores of Jidoka and pull methods increased from 4.65 to 6.44 and from 4.33 to 7.33 in 2010 and from 5.36 to 6.80 and from 5.32 to 7.13, in 2011. These results indicated that participant learning, as measured by performance on the content tests, increased after participating in collaborative sessions. The findings summarized in Table 29 suggest that collaborative sessions, when used for Jidoka and pull methods, have a significant influence on participant learning.

The second research question asked if learners demonstrate improved levels of lean knowledge after participating in simulation sessions. A paired t-test was conducted to compare test scores before and after participating in simulation sessions on both Jidoka and pull methods. Table 30 and Figure 17 summarize the mean scores, t-test results and box plots of Jidoka2 and Jidoka3 and Pull2 and Pull3 from Fall 2010 from Fall 2011.

Paired t-tests comparing Jidoka3 and Jidoka2 revealed a significant difference in mean scores in both 2010 and in 2011 ($p < 0.05$). Hence, these results indicate that participant learning, as measured by performance on content tests on Jidoka methods, increased after participating in simulation sessions (see Table 30). No significant gains in learning after simulation sessions for pull methods were observed.

Table 30: Mean scores and paired t-test analysis results for learning based on test scores before and after participating in simulation sessions.

Year	Survey	n*	Mean		P-value
			Mean scores	Paired t-test statistic	
2010	Jidoka2	28	6.12	-1.59	**0.001**
	Jidoka3	28	7.71		
	Pull2	27	7.48	0.41	0.210
	Pull3	27	7.07		
2011	Jidoka2	26	6.31	-1.61	**0.000**
	Jidoka3	26	7.92		
	Pull2	38	7.08	-0.01	0.860
	Pull3	38	7.09		

*The number of participants varies based on the number of returned surveys that could be matched

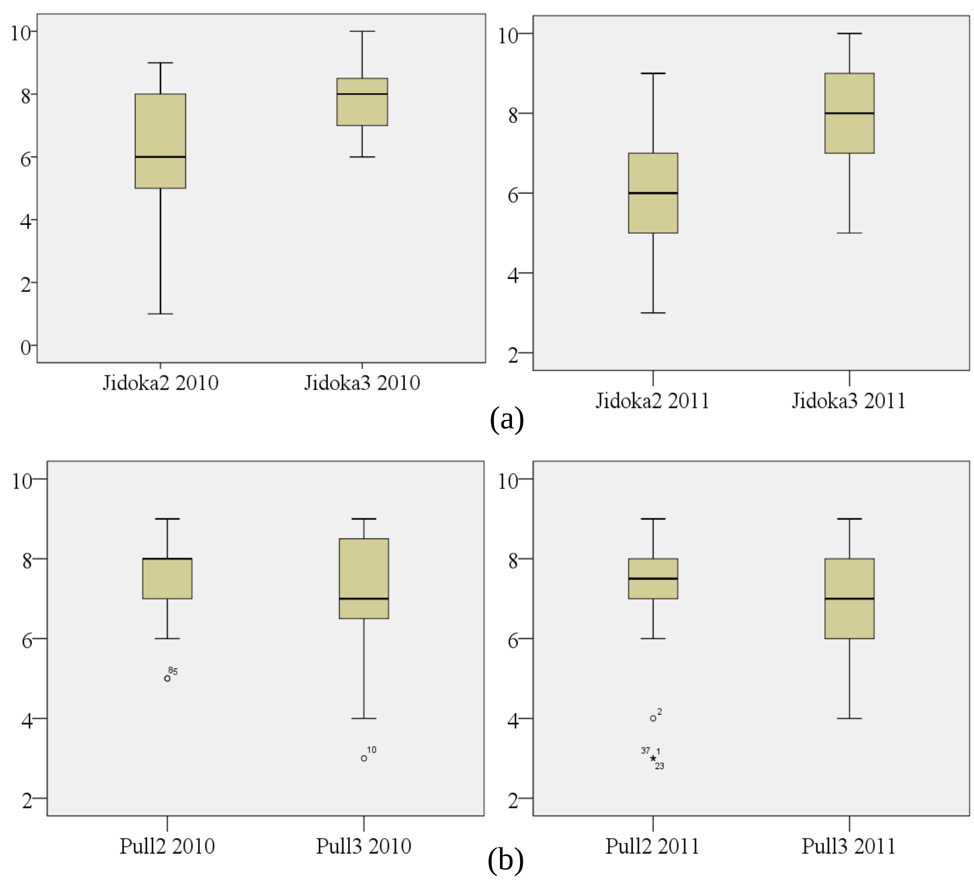


Figure 17: Box plots comparing (a) Jidoka2 and Jidoka 3 during 2010 and 2011(b) pull 2 and pull 3 during 2010 and 2011

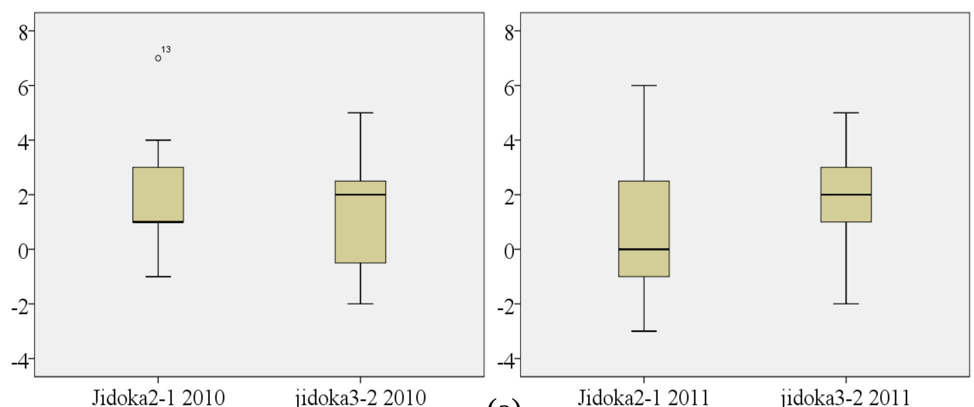
The third research question asked if the type of session affects learning. To answer this research question, gain scores were compared. Gain scores were calculated by taking the difference in Jidoka and pull survey scores from three different measurements: before collaborative session, after collaborative session, and after simulation sessions. Q-Q plots of gain scores were generated. The results showed all gain scores were approximately normally distributed. Paired t-tests of gain scores were analyzed to compare learning as measured by content test scores on both Jidoka and pull. Table 31 summarizes the mean and paired t-test scores for gain scores between each content test for 2010 and 2011.

The results of the paired t-test analysis of gain scores did not indicate any statistically significant differences for Jidoka learning when comparing participation in collaborative and simulation sessions for either 2010 or 2011. There were significant differences in pull gain scores when comparing learning resulting from participating in collaborative and simulation sessions for both 2010 and 2011 (See Table 31). Box plots of these results are summarized in Figure 18. The impact of the use of simulation sessions on self-efficacy beliefs is analyzed next.

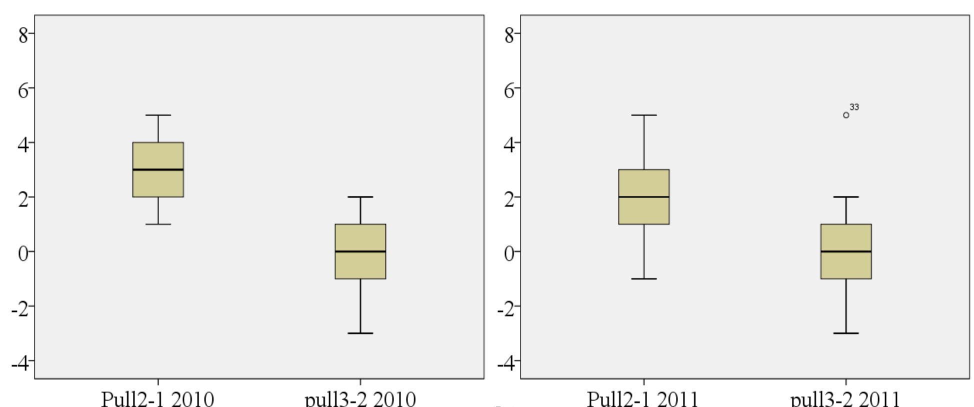
Table 31: Mean gain scores and paired t-test analysis results for learning based on test scores before and after participating collaborative and simulation sessions.

Year	Survey	n*	Mean: Gain scores	Mean: Paired t-test	P-value
2010	Jidoka2-Jidoka1	19	1.53	0.16	0.868
	Jidoka3-Jidoka2	19	1.37		
	Pull2-Pull1	25	-0.32	3.40	**0.000**
	Pull3-Pull2	25	3.08		
2011	Jidoka2-Jidoka1	15	0.87	1.06	0.275
	Jidoka3-Jidoka2	15	1.93		
	Pull2-Pull1	34	1.97	-2.24	**0.000**
	Pull3-Pull2	34	-0.26		

*The number of participants varies based on the number of returned surveys that could be matched



(a)



(b)

Figure18: Box plots comparing (a) Jidoka2-Jidoka1 and Jidoka 3-Jidoka2 gain scores during 2010 and 2011 (b) Box plots comparing pull2-pull1 and pull3-pull2 gain scores during 2010 and 2011

6.6.2 **Self-efficacy Beliefs**

To measure the effects of the use of simulation sessions on learner self-efficacy beliefs, participant self-efficacy beliefs were measured. Four surveys (Jidoka2, Jidoka3, Pull2, and Pull3) each included six self-efficacy belief items and were distributed to participants after collaborative and simulation sessions on either Jidoka or pull. The fourth research question asked if learner self-efficacy beliefs increase after participating in simulation sessions. Paired t-tests were used to compare self-efficacy beliefs survey scores before and after participating in simulation sessions on both Jidoka and pull methods. Table 32 and Figure 19 summarize the mean scores, paired t-test results, and box plots for self-efficacy beliefs for both content areas for 2010 and 2011.

Mean self-efficacy beliefs survey scores after simulation sessions were lower than mean self-efficacy beliefs survey scores measured following collaborative sessions for Jidoka in 2010 and 2011. No statistically significant differences in self-efficacy beliefs scores were observed in Fall 2011. There was, however, a statistically significant difference in self-efficacy beliefs survey scores for pull observed during Fall 2010. The impact of the use of simulation sessions on participant attitudes is analyzed next.

Table 32: Mean scores and paired t-test analysis results for Jidoka and pull self-efficacy beliefs surveys before and after participating in simulation sessions during 2010 and 2011.

Year	Survey		Mean		P-value
		n*	Mean scores	Paired t-test	
2010	Jidoka2 Self-efficacy beliefs	28	3.94	0.11	0.522
	Jidoka3 Self-efficacy beliefs	28	3.83		
	Pull2 Self-efficacy beliefs	23	3.86	-0.24	**0.033**
	Pull3 Self-efficacy beliefs	23	4.10		
2011	Jidoka2 Self-efficacy beliefs	13	3.63	0.15	0.197
	Jidoka3 Self-efficacy beliefs	13	3.48		
	Pull2 Self-efficacy beliefs	32	3.82	0.03	0.742
	Pull3 Self-efficacy beliefs	32	3.79		

*The number of participants varies based on the number of returned surveys that could be matched

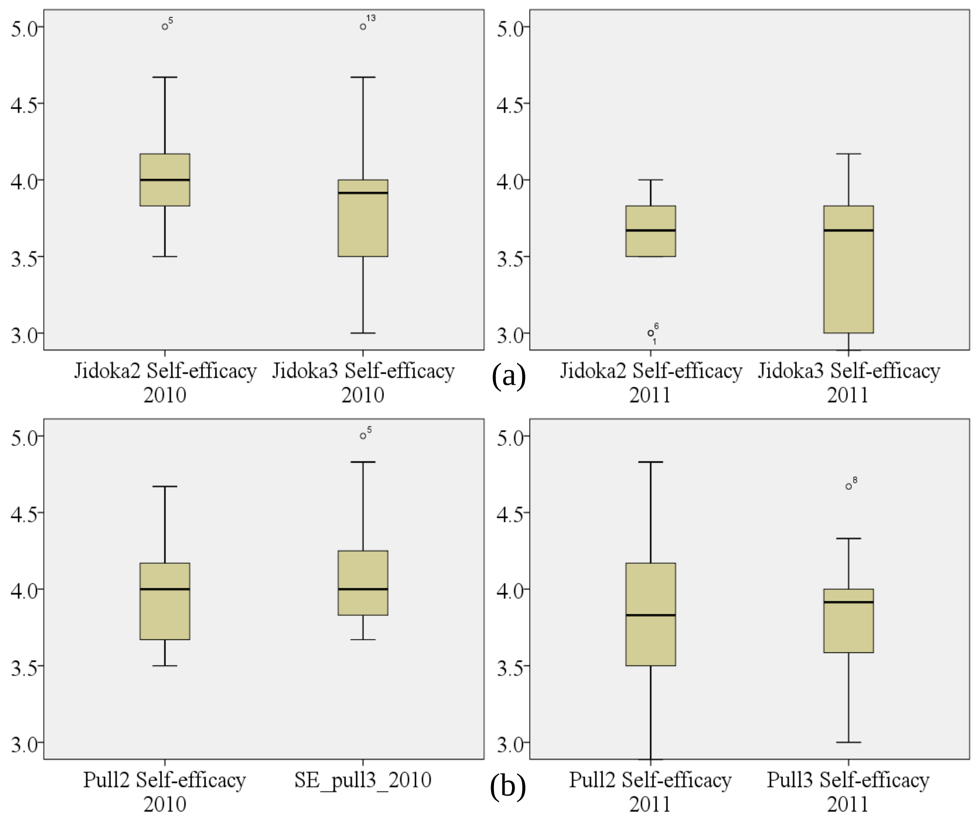


Figure19: Box plots comparing (a) Jidoka2 self-efficacy beliefs and Jidoka3 self-efficacy beliefs during 2010 and 2011 (b) Box plots comparing pull2 self-efficacy and pull3 self- efficacy beliefs during 2010 and 2011

6.6.3 **Attitudes**

To measure the effects of the use of collaborative and simulation sessions on learner attitudes, the way participants felt, thought, and reacted as a result of participating in collaborative and simulation session, was evaluated. Two surveys (Attitude-Collaborative and Attitude-Simulation) with 16 attitudes items were distributed to participants after collaborative and simulation sessions. The fifth research question asked if learner attitudes improved after participating in simulation sessions. Prior to completing analysis of the data, Q-Q plots were created to determine whether or not the data were approximately normally distributed. Representative Q-Q plots for these data are shown in Figure 20.

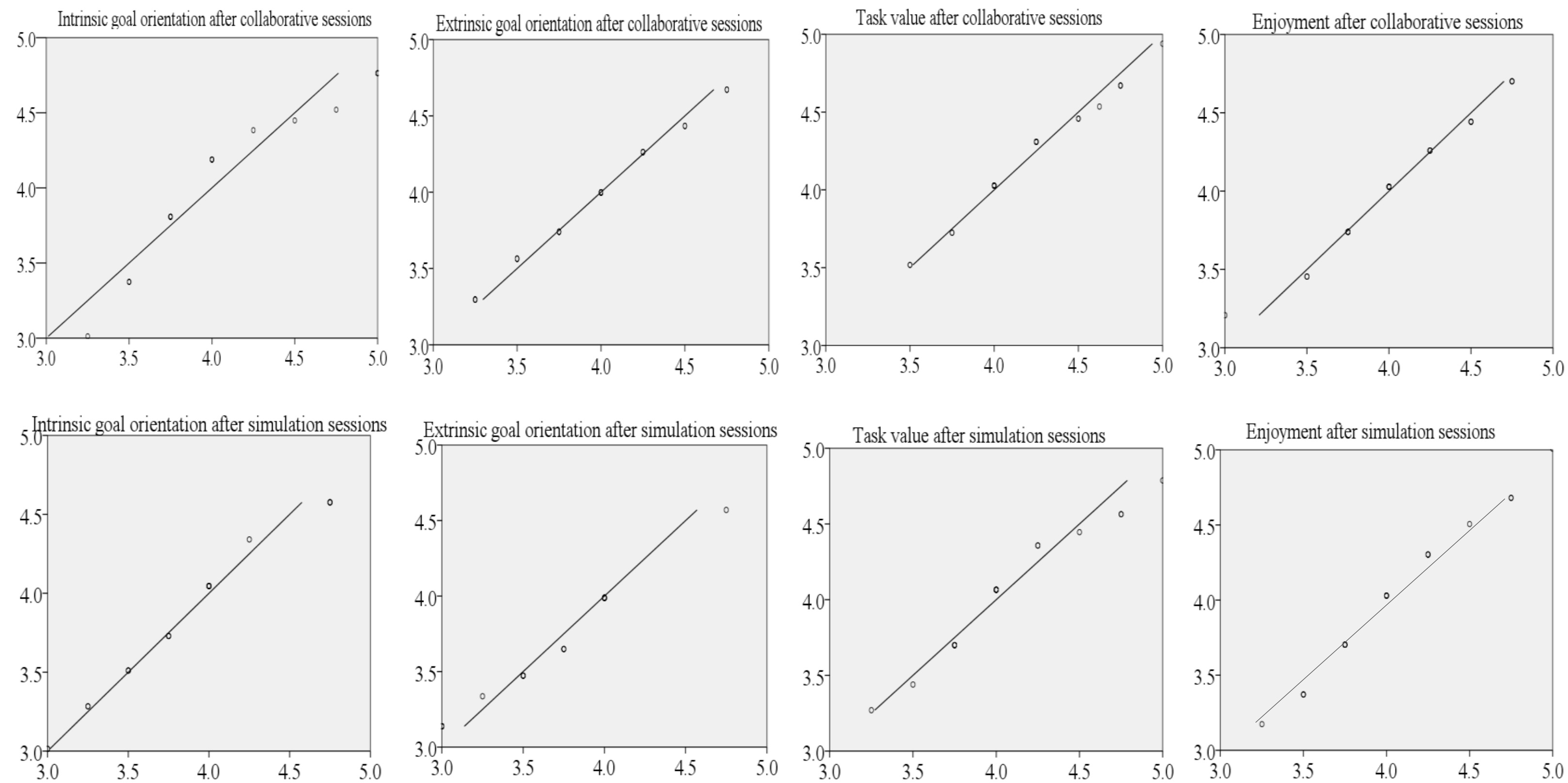


Figure 20: Representative Q-Q plots for attitudes for 2010

Paired t-tests were used to compare attitudes before and after participating in collaborative and simulation sessions. Table 33, Figure 21, and Figure 22 summarize the mean scores, paired t-test analysis results, and box plots for each attitude construct (intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment). As shown in Table 33, only one significant difference (2010 and 2011) was found in participant intrinsic goal orientation scores between collaborative and simulation sessions. The impact of background knowledge on learning and attitudes is analyzed next.

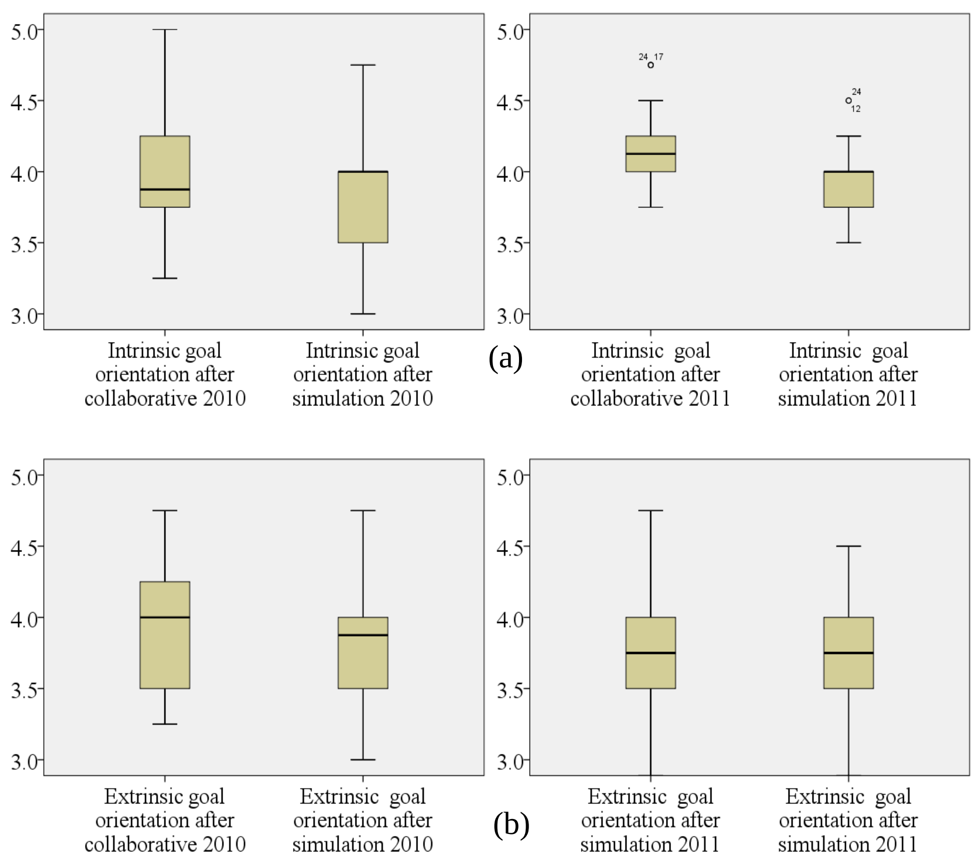


Figure 21: Box plots comparing (a) intrinsic goal before and after simulation during 2010 and 2011 (b) extrinsic goal before and after simulation during 2010 and 2011

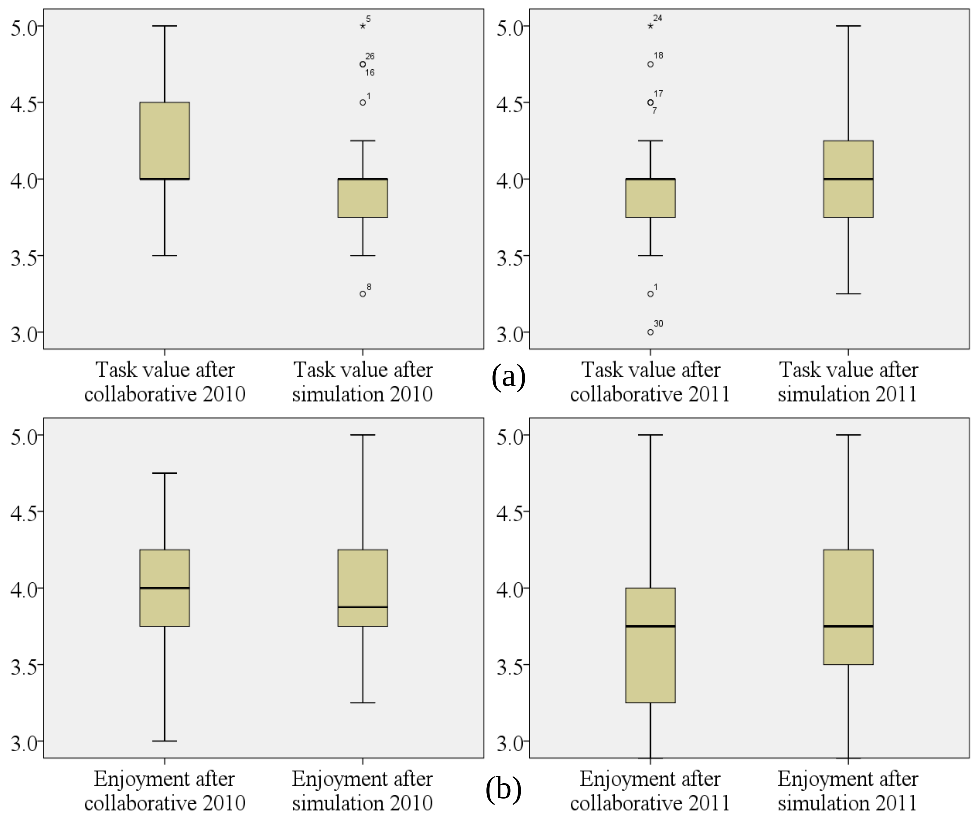


Figure 22: Box plots comparing (a) task value before and after simulation during 2010 and 2011 (b) enjoyment before and after simulation during 2010 and 2011

Table 33: Mean Scores and paired t-test analysis results for participant attitudes survey scores between simulation and collaborative sessions.

Year	Survey	n*	Mean		P-value
			Mean scores	Paired t-test	
2010	Intrinsic goal orientation after collaborative sessions	26	4.04	0.16	**0.026**
	Intrinsic goal orientation after simulation sessions	26	3.88		
	Extrinsic goal orientation after collaborative sessions	26	3.91	0.18	0.122
	Extrinsic goal orientation after simulation sessions	26	3.73		
	Task value after collaborative sessions	26	4.18	0.15	0.067
	Task value after simulation sessions	26	4.03		
	Enjoyment after collaborative sessions	26	4.05	0.16	0.121
	Enjoyment after simulation sessions	26	3.89		
2011	Intrinsic goal orientation after collaborative sessions	38	4.15	0.26	**0.034**
	Intrinsic goal orientation after simulation sessions	38	3.89		
	Extrinsic goal orientation after collaborative sessions	38	3.80	0.11	0.882
	Extrinsic goal orientation after simulation sessions	38	3.69		
	Task value after collaborative sessions	38	3.68	0.02	0.349
	Task value after simulation sessions	38	3.66		
	Enjoyment after collaborative sessions	38	3.62	-0.08	0.452
	Enjoyment after simulation sessions	38	3.70		

*The number of participants varies based on the number of returned surveys that could be matched

6.6.4 **Background Knowledge**

The sixth and seventh research questions asked if the level of learner background knowledge impacted learning and/or attitudes. To measure whether or not the level of background knowledge effects learning and attitudes, differences in content test scores were analyzed. The sixth research question asked if the level of background knowledge affects learning. An analysis of variance (ANOVA) was conducted to explore the effects of background knowledge on lean knowledge and to determine whether any significant differences between groups of participants existed. Participants were divided into two groups to investigate the impact of Jidoka and pull background knowledge. The overall mean score for participant background knowledge on both lean concepts was used to divide participants into two groups.

For Jidoka methods, participants were divided into two groups, one with low background knowledge (scores ≤ 4.76 during Fall 2010 and scores ≤ 5.13 during Fall 2011) and a second group, with higher background knowledge (scores > 4.76 during Fall 2010 and scores > 5.13 during Fall 2011). A participant who received a Jidoka1 score below or equal to 4.76 during Fall 2010 or to 5.13 during Fall 2011 was considered to have low background knowledge on Jidoka methods (low group), while a participant who received a Jidoka1 score above 4.76 during Fall 2010 or 5.13 during Fall 2011 was considered to have higher background knowledge on Jidoka methods.

Similarly, the participants were also divided into two groups for pull methods. The participants who received Pull1 scores below or equal to 4.57 during Fall 2010 or 5.20 during Fall 2011 were considered to have low levels of background knowledge; whereas, the participants who received Pull1 scores above 4.57 during Fall 2010 or 5.20 during Fall 2011 were considered to have higher background knowledge on pull methods. The ANOVA results comparing knowledge after participating in both collaborative and simulation sessions for the low and high background knowledge groups for both Jidoka and pull methods are summarized in Table 34. The results indicate that there was a statistically significant difference in pull learning between high and low background knowledge groups for Fall 2011 participants.

Table 34: Summary of ANOVA results comparing Jidoka and pull learning between low and high Jidoka and pull background knowledge groups.

Year	Survey		Sum of Squares	df	Mean Square	F	P-value
2010	Jidoka3	Between Groups	0.01	1	0.008	0.009	0.927
		Within Groups	25.23	27	0.935		
		Total	25.24	28			
	Pull3	Between Groups	6.36	1	6.361	2.748	0.107
		Within Groups	76.38	33	2.315		
		Total	82.74	34			
2011	Jidoka3	Between Groups	3.81	1	3.813	3.831	0.071
		Within Groups	13.94	14	0.995		
		Total	17.75	15			
	Pull3	Between Groups	7.21	1	7.212	4.298	**0.045**
		Within Groups	63.77	38	1.678		
		Total	70.98	39			

The seventh research question asked if the level of background knowledge has an impact on learner attitudes. The results of this analysis are summarized in Tables 35, 36, 37, and 38. As shown in Table 35, statistically significant differences in intrinsic goal orientation for low and high Jidoka background knowledge groups were observed for both collaborative and simulation sessions in 2010. Moreover, statistically significant differences were observed in enjoyment between low and high background knowledge groups after participating in collaborative sessions for Jidoka in 2011.

Table 35: Summary of ANOVA results comparing motivation (intrinsic goal orientation, extrinsic goals orientation, and task value) and enjoyment between low and high Jidoka background knowledge groups during 2010.

Construct		Sum of Squares	df	Mean Square	F	P-value
Intrinsic Goal Orientation after Collaborative Sessions	Between Groups	1.447	1	1.447	5.984	**0.026**
	Within Groups	4.112	17	0.242		
	Total	5.559	18			
Extrinsic Goal Orientation after Collaborative Sessions	Between Groups	0.132	1	0.132	0.746	0.400
	Within Groups	3.000	17	0.176		
	Total	3.132	18			
Task Value after Collaborative Sessions	Between Groups	0.234	1	0.234	2.060	0.169
	Within Groups	1.931	17	0.114		
	Total	2.164	18			
Enjoyment after Collaborative Sessions	Between Groups	0.154	1	0.154	.807	0.382
	Within Groups	3.253	17	0.191		
	Total	3.408	18			
Intrinsic Goal Orientation after Simulation Sessions	Between Groups	1.658	1	1.658	6.434	**0.021**
	Within Groups	4.381	17	0.258		
	Total	6.039	18			
Extrinsic Goal Orientation after Simulation Sessions	Between Groups	0.000	1	0.000	0.000	0.990
	Within Groups	3.612	17	0.212		
	Total	3.612	18			
Task Value after Simulation Sessions	Between Groups	0.029	1	0.029	0.161	0.693
	Within Groups	3.031	17	0.178		
	Total	3.059	18			
Enjoyment after Simulation Sessions	Between Groups	0.154	1	0.154	0.382	0.545
	Within Groups	6.878	17	0.405		
	Total	7.033	18			

Table 36: Summary of ANOVA results comparing motivation (intrinsic goal orientation, extrinsic goal orientation, and task value) and enjoyment between low and high Jidoka background knowledge groups during 2011.

Construct		Sum of Squares	df	Mean Square	F	P-value
Intrinsic Goal Orientation after Collaborative Sessions	Between Groups	1.913	7	0.273	3.545	**0.041**
	Within Groups	0.385	5	0.077		
	Total	2.298	12			
Extrinsic Goal Orientation after Collaborative Sessions	Between Groups	1.985	7	0.284	4.390	0.061
	Within Groups	.323	5	0.065		
	Total	2.308	12			
Task Value after Collaborative Sessions	Between Groups	1.071	7	0.153	2.370	0.180
	Within Groups	.323	5	0.065		
	Total	1.394	12			
Enjoyment after Collaborative Sessions	Between Groups	2.377	7	0.340	7.408	**0.021**
	Within Groups	0.229	5	0.046		
	Total	2.606	12			
Intrinsic Goal Orientation after Simulation Sessions	Between Groups	1.444	7	0.206	1.707	**0.028**
	Within Groups	0.604	5	0.121		
	Total	2.048	12			
Extrinsic Goal Orientation after Simulation Sessions	Between Groups	3.071	7	0.439	0.777	0.633
	Within Groups	2.823	5	0.565		
	Total	5.894	12			
Task Value after Simulation Sessions	Between Groups	3.283	7	0.469	3.360	0.100
	Within Groups	0.698	5	0.140		
	Total	3.981	12			
Enjoyment after Simulation Sessions	Between Groups	0.682	7	0.097	0.242	0.954
	Within Groups	2.010	5	0.402		
	Total	2.692	12			

As shown in Tables 37 and 38, no statistically significant differences in attitudes were observed between low and high background knowledge groups for pull in 2010 or 2011, respectively. The relationships between type of session, background knowledge and self-efficacy beliefs and learning and attitudes are analyzed next.

Table 37: Summary of ANOVA results comparing motivation (intrinsic goal orientation, extrinsic goal orientation, task value) and enjoyment between low and high pull background knowledge groups during 2010.

Construct		Sum of Squares	df	Mean Square	F	P-value
Intrinsic Goal Orientation after Collaborative Sessions	Between Groups	0.060	1	0.060	0.206	0.655
	Within Groups	5.518	19	0.290		
	Total	5.577	20			
Extrinsic Goal Orientation after Collaborative Sessions	Between Groups	0.017	1	0.017	0.071	0.793
	Within Groups	4.543	19	0.239		
	Total	4.560	20			
Task Value after Collaborative Sessions	Between Groups	0.001	1	0.001	0.008	0.930
	Within Groups	3.165	19	0.167		
	Total	3.167	20			
Enjoyment after Collaborative Sessions	Between Groups	0.023	1	0.023	0.106	0.749
	Within Groups	4.090	19	0.215		
	Total	4.113	20			
Intrinsic Goal Orientation after Simulation Sessions	Between Groups	0.287	1	0.287	1.201	0.287
	Within Groups	4.540	19	0.239		
	Total	4.827	20			
Extrinsic Goal Orientation after Simulation Sessions	Between Groups	0.234	1	0.234	1.298	0.269
	Within Groups	3.427	19	0.180		
	Total	3.661	20			
Task Value after Simulation Sessions	Between Groups	0.011	1	0.011	0.061	0.807
	Within Groups	3.352	19	0.176		
	Total	3.363	20			
Enjoyment after Simulation Sessions	Between Groups	0.035	1	0.035	0.098	0.757
	Within Groups	6.786	19	0.357		
	Total	6.821	20			

Table 38: Summary of ANOVA results comparing motivation (intrinsic goal orientation, extrinsic goal orientation, task value) and enjoyment between low and high pull background knowledge groups during 2011.

Construct		Sum of Squares	df	Mean Square	F	P-value
Intrinsic Goal Orientation after Collaborative Sessions	Between Groups	0.033	1	0.033	0.218	0.644
	Within Groups	4.605	30	0.154		
	Total	4.639	31			
Extrinsic Goal Orientation after Collaborative Sessions	Between Groups	0.021	1	0.021	0.091	0.765
	Within Groups	6.790	30	0.226		
	Total	6.811	31			
Task Value after Collaborative Sessions	Between Groups	0.048	1	0.048	0.524	0.475
	Within Groups	2.757	30	0.092		
	Total	2.805	31			
Enjoyment after Collaborative Sessions	Between Groups	0.239	1	0.239	0.555	0.462
	Within Groups	12.940	30	0.431		
	Total	13.180	31			
Intrinsic Goal Orientation after Simulation Sessions	Between Groups	0.251	1	0.251	1.295	0.264
	Within Groups	5.804	30	0.193		
	Total	6.055	31			
Extrinsic Goal Orientation after Simulation Sessions	Between Groups	0.003	1	0.003	0.013	0.911
	Within Groups	6.052	30	0.202		
	Total	6.055	31			
Task Value after Simulation Sessions	Between Groups	0.039	1	0.039	0.218	0.644
	Within Groups	5.413	30	0.180		
	Total	5.453	31			
Enjoyment after Simulation Sessions	Between Groups	0.028	1	0.028	0.060	0.809
	Within Groups	13.814	30	0.460		
	Total	13.842	31			

6.6.5 **Relationship between Type of Session, Background Knowledge, Self-efficacy Beliefs, and Learning and Attitudes**

The eighth and ninth research questions asked whether there is a relationship between type of session, self-efficacy beliefs, and background knowledge and learning or learner attitudes. A multiple regression analysis was used to determine which variables (type of session, background knowledge, and/or self-efficacy beliefs) affect learning and attitudes. The dependent variables were learning and attitudes. Multiple regression is a statistical analysis technique used to study the relationship among variables (Chatterjee, Hadi, & Price, 2000). A dummy variable was created, for which "0" represented collaborative sessions and "1" represented simulation sessions. The multiple regression was developed using a forward selection method. In the initial step, the model starts without variables, and then the first variable, which has the highest simple correlation, was entered to the analysis model. The final model contains all variables that make significant contributions to the dependent variable based on an F test. The statistical model used in this study can be specified as shown in Equation 1.

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n + e \qquad \text{(Eq.1)}$$

Where:

Y is the dependent variable; X_1, X2, X3… X_n are denoted as the independent variables; "a" is the intercept constant; b_1, b_2, $b_3 \dots$ b_n are denoted as the regression coefficients, and e is the error term.

The multiple regression analyses were performed for each lean method (Jidoka and pull) and for both sets of data (Fall 2010 and Fall 2011). To address the eighth research question, four multiple regression analyses were generated to find out if there was a relationship between type of session, background knowledge, and self-efficacy beliefs on learning. First, a regression model for Jidoka learning for 2010 was created. Only type of session was retained in the model, while background knowledge and self-efficacy beliefs were removed from the final model when forward selection was used. The findings showed type of session had a direct positive and significant effect on learning Jidoka methods, F (1,34) = 6.213, p = 0.018, R^2 = 0.16, based on data collected in the Fall of 2010. A total of 16% the variance in learning Jidoka methods was explained by type of session. The final regression equation is shown in Equation 2.

$$\textit{Jidoka learning (2010)} = 6.44 + 1.33 * \textit{Type of session} \qquad \text{(Eq.2)}$$

Second, a regression model for pull learning for 2010 was created. Only background knowledge was retained in the model, while type of session and self-efficacy beliefs were removed from the final model when forward selection was used. Background knowledge had a direct positive and significant effect on learning pull methods , F (1, 42) = 5.065, p = 0.030, R^2 = 0.11, based on data collected during the Fall of 2010. A total of 11% the variance in learning pull methods was explained by learner background knowledge. The final regression equation is shown in Equation 3.

$$\textit{Pull learning (2010)} = 7.13 + 0.83 * \textit{background knowledge} \qquad \text{(Eq.3)}$$

Third, a regression model for Jidoka learning for 2011 was created. Both type of session and background knowledge were retained in the final model. Both type of session and background knowledge had direct positive and significant effects on learning Jidoka methods, F (2, 23) = 20.345, p = 0.000, R^2 = 0.80, based on data collected during the Fall of 2011. A total of 80% the variance in learning Jidoka methods was explained by type of session and learner background knowledge. The final regression equation is shown in Equation 4.

$$\textit{Jidoka learning (2011)} = 4.45 + 1.77 * \textit{Type of session} + 2.41 * \textit{background knowledge} \quad \text{(Eq.4)}$$

Fourth, a regression model for pull learning for 2011 was created. Only background knowledge had direct positive and significant effect on learning pull methods , F (1, 64) = 9.874, p = 0.003, R^2 = 0.13, based on data collected during the Fall of 2011. A total of 13% the variance in learning pull methods was explained by learner background knowledge. The final regression equation is shown in Equation 5.

$$\textit{Pull learning (2011)} = 6.71 + 0.97 * \textit{background knowledge} \quad \text{(Eq.5)}$$

To address the ninth research question, additional multiple regression analyses were completed to find out if there was a relationship between type of session, background knowledge, and self-efficacy beliefs for the four different learner attitudes, including motivation (intrinsic goal orientation, extrinsic goal orientation, task value) and enjoyment. Using data collected and related to attitudes on Jidoka learning in Fall 2010, self-efficacy beliefs was a significant predictor of task value, F (1, 16) = 8.517, p = 0.010, R^2 = 0.35 and enjoyment, F (1, 16) = 7.666, p =0.014, R^2 =

0.57. A total of 35% the variance in learner task value and a total of 57% of the variance in learner enjoyment were explained by self-efficacy beliefs. Self-efficacy beliefs had direct positive and significant effect on learner task value and on enjoyment as shown in Equation 6 and Equation 7.

$$\textit{Task value} = 1.89 + 0.53 * \textit{Self-efficacy beliefs}; \qquad \text{(Eq.6)}$$

$$\textit{Enjoyment} = 0.70 + 0.80 * \textit{Self-efficacy beliefs} \qquad \text{(Eq.7)}$$

No significant relationships were found between type of session, background knowledge, and self-efficacy beliefs on any measured attitude related to pull learning.

Using data collected and related to attitudes on Jidoka learning in Fall 2011, the results showed background knowledge was a significant predictor of learner intrinsic goal orientation, $F = 5.216$, $p = 0.033$, $R^2 = 0.46$, whereas; self-efficacy beliefs, were significantly predictive of leaner extrinsic goal orientation, $F = 6.213$, $p = 0.001$, $R^2 = 0.42$. A total of 46% the variance in learner intrinsic goal motivation and a total of 42% the variance in learner extrinsic goal motivation were explained by self-efficacy beliefs. The resulting regression equations are shown in Equation 8 and Equation 9.

$$\textit{Intrinsic goal orientation} = 4.13 - 0.49 * \textit{background knowledge} \qquad \text{(Eq.8)}$$

$$\textit{Extrinsic goal orientation} = 0.94 + 0.77 * \textit{Self-efficacy beliefs} \qquad \text{(Eq.9)}$$

No significant relationships were found between type of session, background knowledge, self-efficacy beliefs, and any measured pull learning in Fall 2011. Table 39 summarizes all research questions and major findings from this research study.

Positive and significant relationships are depicted as a “+”; whereas, negative or insignificant relationship are indicated with a “0”.

Table 39: Summary of research questions and major findings from Fall 2010 and Fall 2011

Research Questions	Lean Method	Fall 2010	Fall 2011
Collaborative sessions do not affect learning as measured by learning outcome achievement.	Jidoka methods	+	+
	Pull methods	+	+
Simulation sessions do not affect learning as measured by learning outcome achievement.	Jidoka methods	+	+
	Pull methods	0	0
The type of session does not affect learning as measured by learning outcome achievement.	Jidoka methods	0	0
	Pull methods	+	+
Simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy survey scores.	Jidoka methods	0	0
	Pull methods	+	0
Simulation sessions do not affect attitudes as measured by learner motivation and enjoyment survey scores.	Intrinsic goal	+	+
	Extrinsic goal	0	0
	Task value	0	0
	Enjoyment	0	0
The level of background knowledge does not affect learning as measured by learning outcome achievement	Jidoka methods	0	0
	Pull methods	0	+
The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores. • Jidoka background knowledge after collaborative sessions	Intrinsic goal	+	+
	Extrinsic goal	0	0
	Task value	0	0
	Enjoyment	0	+
The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores • Jidoka background knowledge after simulation sessions	Intrinsic goal	+	+
	Extrinsic goal	0	0
	Task value	0	0
	Enjoyment	0	0

Research Questions	Lean Method	Fall 2010	Fall 2011
The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores. • Pull background knowledge after collaborative sessions	Intrinsic goal Extrinsic goal Task value Enjoyment	0 0 0 0	0 0 0 0
The level of background knowledge does not affect learner attitudes as measured by motivation and enjoyment survey scores. • Pull background knowledge after simulation sessions	Intrinsic goal Extrinsic goal Task value Enjoyment	0 0 0 0	0 0 0 0

6.7 **Discussion and Conclusions**

The purpose of this study was, first, to examine the effects of collaborative and simulation sessions, focused on teaching and training lean principles and methods, on increasing participant learning and in improving learner attitudes. The second purpose of this study was to determine if differences in lean background knowledge result in differences in learning, self-efficacy beliefs, and/or attitudes. The third purpose was the explore the relationships between all of these variables and learning and attitudes.

Lean manufacturing is a powerful improvement methodology used by many organizations to dramatically reduce or eliminate inefficiencies, but a number of studies have cited failed lean manufacturing implementations. The majority of lean failures are due to the lack of a real understanding of lean manufacturing concepts and a lack of understanding on how to implement lean manufacturing methods (Nordin, Deros, & Wahab, 2010). Consequently, several consulting companies, expert trainers, and universities are working to identify effective ways to improve teaching and learning to enhance learner skills, to improve attitudes toward learning, and to provide experiences that create the skills needed to successfully apply lean methods. Although the use of nontraditional teaching techniques, such as collaborative learning and/or simulation in lean education and training programs may be effective, the relationship between these types of sessions and lean learning is not well studied. The results of this study provide guidance to instructors on how to improve learner skills in lean methods.

A first goal of this research study was to investigate the use of collaborative and simulation sessions on learning specific to two lean methods: Jidoka and pull. The learning variable showed statistically significant differences in mean scores before and after participating in collaborative sessions for both lean methods. These research findings validate the value of collaborative activities and are supported by previous research (Stump et al., 2011). Stump et al. studied of the relationships between collaborative learning in engineering courses, self-efficacy for learning course material, knowledge building behaviors, and course grades. Stump et al. found the use of collaborative learning strategies improved student self-efficacy for learning course material and improved course grade. In other domains, collaborative activities were found to positively affect individual learning achievement. Cabrera et al. (2002), for example, obtained similar results after examining the role of collaborative learning in personal development, understanding science and technology, appreciation for art, and analytical skills. Moreover, Prince (2004) found that students gained more knowledge and skill with collaborative learning when compared with traditional teaching methods. Based on these research findings, the benefits of the collaborative sessions on learning were seen for both methods (Jidoka and pull). One reason that collaborative sessions could positively impact learning is that collaborative sessions include instructional strategies such as brainstorming and discussion. These positive effects on learning suggest that collaborative learning sessions can be used as a supplemental to traditional teaching methods and in support of academic achievement.

Future research is needed to investigate the use of collaborative sessions with other lean methods.

The second research question was to compare the impact of simulation sessions and collaborative sessions on learning. Findings from an analysis of mean test scores on lean methods after simulation sessions found improvement in mean scores after simulation sessions for only Jidoka methods. The research results indicate the content of lean methods is an important factor. Although pull methods are well known, the concepts of pull methods are difficult to grasp and learn for most people. Previous studies have suggested that simulation may be more effective than other teaching methods, depending on the context, topic, and method (Cant & Cooper, 2010). However, participants generally performed well on the pull content questions, correctly answering 7 out of 10 questions before the simulation sessions were conducted, leaving less room for improvement. Participants with lower scores before the simulation session received almost identical scores after participating in the simulation session.

By analyzing gain scores, the difference in impact between type of sessions can be better understood. For both lean methods, the results revealed there were only statistically significant differences from learning pull methods following collaborative sessions. In addition, although there were no differences in learning gains between collaborative and simulation sessions, it is interesting to note that scores did increase for Jidoka during the Fall of 2011. In the future, a similar study could be repeated using the same lean methods or other lean methods to replicate and extend these results. Moreover, future research may include the development of a knowledge test that is more comprehensive and can detect differences in learning more precisely. Because all the questions developed for this study were multiple choice, some correct answers could have been obtained by guessing. Based on the results from this research study, learning improved immediately after collaborative sessions, but additional learning did not seem to result from participation in simulation sessions.

Another goal of this research study was to determine how participant self-efficacy and attitudes are impacted by the use of different types of sessions when teaching and training lean principles and methods. According to the results of paired t-test analyses of learner self-efficacy beliefs after participating in simulation sessions, the findings revealed that there was a statistically significant difference only in participant self-efficacy survey scores related to pull methods and only in Fall 2010. Thus, the findings do not completely support the research hypothesis that participant self-efficacy beliefs would become more positive after simulation sessions. The study also found that learners have slightly decreased self-efficacy beliefs, except for pull methods during the Fall of 2011. This may be due to the fact that in simulation sessions, learners were required to take responsibility for learning themselves. Learners might not have been ready for a learning environment in which they were expected to take initiative and learn independently. According to Bandura (1977), physiological state is one of four experience sources that affect individual self-efficacy beliefs. It would appear that the feelings of stress or pleasure of the learning environment may result in a lower level of self-efficacy beliefs after participating in simulation sessions. Perhaps simulation sessions are best left for advanced learners, who can take responsibility for their own learning.

According to results of the paired t-test analyses of learner attitudes after participating in simulation sessions, the research results indicated no overall differences between collaborative and simulations sessions in learner extrinsic goal orientation, task value, or enjoyment. A difference in intrinsic goal orientation was observed after participation in simulation sessions, which is consistent with the results of previous studies. For example, Liu, Cheng, and Huang (2011) indicated that learning through game simulation can improve student intrinsic goal motivation. The results also showed that learner attitudes decreased slightly after participating in simulation sessions, except for learner enjoyment during the Fall of 2011.

Even though these finding do not completely support the hypotheses that participant self-efficacy beliefs and attitudes would increase and improve after simulation sessions, the mean scores for self-efficacy beliefs and attitudes were generally high before and after simulation sessions, averaging between 3.5 and 4.0 on a 5-point Likert scale. These results are indicative of a high level of self-efficacy beliefs and positive attitudes. Although the findings showed no significant change in self-efficacy beliefs and attitudes after simulation sessions, future research could be focused on determining if the collaborative sessions that preceded the simulation sessions influenced learner self-efficacy beliefs and attitudes. This could be evaluated by measuring self-efficacy beliefs and attitudes prior to each type of session.

The next goal was to investigate whether background knowledge impacted learning and/or learner attitudes. Previous studies have shown that background knowledge affects academic outcomes (Jacobs, 2002; Thompson & Zamboanga, 2003). The level of background knowledge had a mixed effect on learning, and the research results show that the level of background knowledge did impact learner intrinsic goal motivation, but overall did not impact other attitudes (extrinsic goal orientation, task value, or enjoyment). The findings also revealed that the effects of background knowledge may be different for different topical knowledge areas. For Jidoka methods, the findings showed no differences between learners with low and high levels of background knowledge. However, statistically significant differences appeared between low and high background knowledge groups in relation to learning pull methods in the Fall of 2011. This significant difference, however, was not observed in the data collected in the Fall of 2010. The results from this study do not fully support previous research in which different levels of background knowledge were found to play a role in learning (Hailikari, Katajavuori, & Lindblom-Ylanne, 2008; Williams & Lombrozo, 2010).

For studying the effects of different levels of background knowledge on learner attitudes, the results of the study showed that the low and high level of background knowledge was a significant and reliable predictor of participant intrinsic motivation related to Jidoka methods based on data collected in 2010 and 2011. However, low and high levels of background knowledge did not have a significant effect on learner attitudes related to pull methods for either 2010 or 2011. It appears that learners with higher levels of background knowledge on Jidoka methods were more likely to engage in learning sessions that were challenging, interesting, and important to them. However, background knowledge was not a significant predictor of other attitudes. The research findings indicate that the lean methods being taught may impact learning and attitudes.

The final goal of this research was to determine whether relationships between type of session, background knowledge, and self-efficacy beliefs on learning or learner attitudes existed. The findings confirm that there are some relationships between type of session and background knowledge when learning lean principles and methods. A significant relationship was found between type of session and background knowledge on learning, however, the coefficients of determination were quite small. For Jidoka methods during the Fall of 2010, the findings revealed that the type of session was a significant predictor of learning. In contrast, based on data from Fall 2011, it appears that the combined effects of the type of session and background knowledge influenced learning; whereas, for pull learning the effect of background knowledge was seen for both years. The relationship between learner background knowledge and learning is consistent with findings in some previous research (Roschelle, 1995; Dochy et al., 1999; and Braasch & Goldman, 2010). Further studies are needed to establish whether the relationship between type of session and background knowledge for learning other lean methods also exist. Overall, these findings do support the impact of background knowledge on learning. A background knowledge test during the first class session may help instructors and educators tailor the teaching methods to better support subsequent learning.

Results of the regression analysis for learner attitudes revealed the overall positive effects of self-efficacy beliefs on some learner attitudes, e.g. extrinsic goal orientation, task value, and enjoyment for Jidoka; whereas, background knowledge was a significant predictor only for intrinsic goal orientation for either 2010 or 2011. Significant impacts of type of session, background knowledge, or self-efficacy were not observed for pull attitudes. Many previous studies found self-efficacy beliefs played an important role in improving academic attitudes and learning. For example, Nicolaidou and Philippou (2003) found a significant relationship between student self-efficacy beliefs in learning mathematics and attitudes and found that self-efficacy beliefs played an important role in predicting achievement in mathematical problem-solving. The findings of this research are consistent with a study by Partin et al. (2011), which found a significant relationship between student self-efficacy beliefs and attitudes towards learning biology.

This research study has some limitations. One limitation of this study is the number of participants. In order to increase the generalizability of the research findings, future research should consider ways to increase the number of participants. A second limitation was the structure of the course used in this research study. The course consisted of traditional teaching methods followed by collaborative sessions, followed by simulation sessions. Future research may be needed in order to investigate the influence of the use of collaborative and/or simulation sessions on learning lean principles and methods in universities or courses where only lectures are used. Lastly, learner attitudes and self-efficacy beliefs were measured only after learners participated in both collaborative and simulation sessions. This study could be extended to measure learner attitudes and self-efficacy beliefs prior to each type of session, as well as following each type of sessions. This would enable a better measurement of the effects of using either or both collaborative learning and simulation sessions.

6.8 **Contribution**

The findings of this research support the benefit of collaborative sessions and, to some extent, the use of simulation. The findings support, to a lesser extent, the role of these interventions on learner attitudes. The findings of this study do have important implications for lean educators. First, the results confirm that collaborative sessions can be implemented successfully in lean courses, especially in higher education settings. The findings also indicated that the impact of the use of simulation for teaching and training lean principles and methods seems to be dependent on the type of lean method being taught. While additional research is needed to extend this understanding beyond the two methods studied, educators can try one or both of these types of sessions with some likelihood of improving learning and knowing that they will not have a negative impact.

An additional important result from this research study is that the lean method content area appears to influence these effects. The implication for educators is that it is important to select suitable teaching techniques for the topic being taught. Selecting suitable teaching techniques, such as collaborative sessions, simulation sessions, or a combination of both types of sessions may depend on the content area.

Finally, the level of background knowledge was also found to influence learning and attitudes. Thus, the level of background knowledge possessed by students should be well understood by educators. By understanding learner levels of background knowledge before selecting teaching methods (non-traditional and traditional teaching methods), instructors may be able to provide a more effective learning environment.

6.9 **References**

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THE IMPACT OF COLLABORATIVE AND SIMULATION SESSIONS
ON
LEARNING LEAN PRINCIPLES AND METHODS:
A MULTI-INSTITUTIONAL STUDY

Juthamas Choomlucksana and Toni L. Doolen

7. The Impact of Collaborative and Simulation Sessions on Learning Lean Principles and Methods: A Multi-institutional Study

7.1 Abstract

While some previous research has shown the impact of using collaborative or simulation sessions on learning lean methods in professional training, few studies have investigated the impact of these types of sessions on learner perceptions in higher education. Previous studies in other areas have shown learner perceptions, including self-efficacy beliefs and attitudes, play an essential role in motivation and in academic outcome achievement (Zimmerman, 2000). This study sought to examine the impact of self-efficacy beliefs and attitudes resulting from the use of collaborative and simulation sessions in teaching and training lean principles and methods. Participants from this study were undergraduate students from three universities. Data were analyzed using paired t-tests. Based on the analyses, it was found that the sequence of the type of session used for teaching lean principles and methods impacted learner self-efficacy, while learning lean principles and methods. Overall, the findings indicated that the use of these types of session has an impact on learner self-efficacy and on some learner attitudes.

Keywords

Lean manufacturing principles and methods, collaborative learning, simulation, self-efficacy beliefs, attitudes

7.2 **Introduction**

Even though lean manufacturing has been around since the early 1980s, many companies fail in efforts to transform to a lean organization (Santos; 1999; Johansen et al., 2002). The failure rate of lean transformations is estimated to be as high as 70%-98%, based on the Association for Operation Management (APICS), a nonprofit international education organization (Nadler, 2010). Similarly, Rubrich (2004) stated that only five percent of organizations have truly implemented lean manufacturing. One of the main factors potentially leading to lean transformation failures may be the lack of clear targets or direction. Effects of poor training and lack of awareness of lean principles and methods (Schonberger, 2007) can result in long learning periods and lean transformation failure. Lean manufacturing, just like any other continuous improvement method, requires not only a deep understanding of the principles and methods of lean manufacturing, but also the ability to adapt what has been learned to a given situation. Since lean methods are not standardized, training and teaching lean methods to learners particularly those learners who do not have work experience can be quite a challenge.

Dukouska-Popovska, Madsen, and Nielsen (n.d.) stated "the challenge, when teaching students, is to create a context so that they can imagine and understand why lean philosophy is important and how it can work. On the other hand, when teaching employees/practitioners, the challenge is to translate lean thinking into their own context and facilitate their learning process through the different issue of lean thinking (1)." Lean manufacturing implementations often incorporate a number of methods, such as value stream mapping, standardized work, kaizen, Kanban, Visual control, 5S, and Poka-Yoke. Teaching and training of lean must provide learners with an understanding of lean principles and methods, as well as some experience in applying lean methods.

One reason many trainers and educators have attempted to include non-traditional teaching methods in courses and workshops is the hope that these teaching methods will improve learning and help learners gain experience in applying what have learned to real world situations/environments. Even though traditional teaching methods are well-organized and familiar to most learners, researchers have identified certain benefits of using non-traditional teaching methods over traditional teaching methods. For example, Deutsch (1962) and Johnson and Johnson (1989) proposed that cooperative learning activities provide positive interdependence among learners. Cooperative and collaborative learning have similar meanings. Harasim (1990) defined collaborative as a group learning that encourages learners to work together on academic tasks, which differ from traditional teaching methods where the instructor is the sole source of knowledge or skills. Researchers found that cooperative learning activities not only improve learner abilities to reach learning goals, but also help learners understand the importance of teamwork. Similarly, Johnson and Johnson (1989) found cooperative learning improved learning outcome achievement, as well as learner motivation, classroom socialization, confidence, and attitudes. Hinde and Kovac (2001) studied traditional and non-traditional classrooms. The results showed that learners received higher scores in classrooms where active learning methods were used. Active learning can be defined as “any instructional method that engages learners in the learning process” (Prince, 2004, p.1). Other researchers have studied the differences between traditional and non-traditional teaching methods on learning. Hake (1988) compared learning outcomes in an introductory physics course between two classroom techniques (lecture based and interactive-engagement methods). Over 6,500 learners enrolled in 62 introductory physics courses participated. Data were collected from high schools, colleges, and universities. During the study, learners were asked to complete surveys using the original Halloun-Hestenes Mechanics Diagnostic test (MD), Force Concept Inventory (FCI), and problem solving mechanical baseline test. Both MD and FCI were used to evaluate student understanding of the basic concepts of mechanics. The researchers found that classrooms using interactive-engagement methods improved problem-solving ability and increased learning of mechanic concepts compared with other techniques. Dempsey et al. (1997) conducted a study where the use of simulations and games was observed to improve learning in preschools, K-12 classrooms, universities, military settings, and business domains. Similarly, Akinsola and Animasahun (2007) explored the effect of using simulations for teaching mathematics in secondary schools. The researchers applied two teaching methods to test groups: a traditional teaching method and simulation. The results indicated that simulation improved learner performance and attitudes toward mathematics, more than the non-traditional teaching methods.

Studies indicate that there is a trend towards increasing the use of non-traditional teaching methods, such as simulation and collaborative learning activities in the teaching of lean manufacturing principles and methods in both industrial and academic areas. For example, some universities e.g., Massachusetts Institute of Technology, Ohio University, and the University of Kentucky, have developed and used simulations to teach and train staff in lean principles and methods. Similarly, Verma (2003) reported survey results from a lean training program in the shipbuilding and repair industry that suggest that at least 17 simulations have been used in lean manufacturing training programs.

A variety of lean principles and methods including 5S, setup reduction, value stream mapping are often taught. Many consulting organization use non-traditional teaching techniques e.g., simulations, games, collaborative learning activities, and hands-on exercises or activities as part of training sessions with great success. For example, The Lean Enterprise Institute (LEI) was established to facilitate activities related to lean education and training in 1997. The LEI has about 60 university schools e.g., Arizona State University, Indiana State University, University of Dayton, and The University of Warwick (UK) around the world. Studies have indicated that the use of non-traditional teaching techniques have a direct positive effect on lean learning. Recent studies also provide some support to indicate that use of these teaching techniques also increase learner self-efficacy beliefs and imprve attitudes. High levels of self-efficacy beliefs and positive attitudes have been shown to have a significant impact on learner performance and achievement (Mahyuddin et al., 2006; Adeyemo, 2007; Isman & Celikli, 2009; Lunenburg, 2011) in other domains. Previous reseach on self-efficacy beliefs and attitude are described next.

7.3 **Self-efficacy Beliefs**

Self-efficacy beliefs are an important factor to consider in improving learning performance and outcomes. Albert Bandura (1986) proposed the concept of self-efficacy beliefs, which refers to a personal belief that one has the capability to learn or perform a particular behavior to complete a task and achieve a desire outcome. Bandura (1986) specifically defined self-efficacy beliefs as, “people’s judgments of their capabilities to organize and execute a course of action required to attain designated types of performance (p.391).” Self-efficacy beliefs reflect people’s belief about whether “they can” or “they cannot” commit to a specific task. People with a high level of self-efficacy not only believe that they can do or complete a task, but they also work harder and show more persistence, leading to greater success. In contrast, people with low levels of self-efficacy do not believe that they can do or complete a task and, as a result, try to avoid the task. The level of self-efficacy beliefs has an impact on the level of effort required and the amount of time required when confronting a task and/or obstacle (Siegle, 2000). Different beliefs related to individual abilities and/or levels of self-efficacy may influence people’s ability to work. Bandura (1977) stated that people learn not only through experiences but also from observing others perform and observing outcomes. People then copy those behaviors. Self-efficacy beliefs have been found to enhance an individual’s ability to face difficulties and to sustain efforts to successfully accomplish a task.

Bandura pointed out four experience sources that can affect self-efficacy beliefs. The four main sources are mastery experience, vicarious experience, verbal or social persuasion, and physiological factors. Mastery experience refers to an individual's previous task experiences and performance. The level of self-efficacy can decrease or increase depending on individual past experience. Likewise, people who fail in similar task will have lower levels of self-efficacy, which will affect the learner's ability to succeed at new tasks.

Vicarious experience results from observing others experience or perform successes or failures in a similar task or situation. The level of self-efficacy beliefs can decrease or increase depending on observations of others experiences or performance outcomes. For example, one's level of self-efficacy beliefs can increase by seeing others successfully accomplish a task. Bandura (1994) stated, "seeing people similar to oneself succeed by sustained effort raises observers' beliefs that they too possess the capabilities to master comparable activities and to succeed." The level of self-efficacy may increase or decrease depending on encouragement and/or discouragement received from other people. For example, people will have a high level of self-efficacy when receiving encouragement or positive feedback or input from trusted or influential others. On the other hand, negative feedback decreases the level of self-efficacy. Social persuasion results from judgments, feedback, or support from others. Finally, the level of self-efficacy is also influenced by physiological factors (e.g., moods, emotional, states, physical reactions, and stress situations). For example, people experiencing high stress, may exhibit decreased levels of self-efficacy, which in turn can result in task failure. On the other hand, people with no stress may show higher levels of self-efficacy.

The concept of self-efficacy has been shown to influence motivation, task performance, and individual goal setting. One recent study by Lunenburg (2011) showed that high levels of self-efficacy is strongly linked to learning, task performance, and individual goal setting. Lunenburg (2011) stated that the reason that self-efficacy beliefs has a significant impact on learning, motivation, and performance is that people try to learn or do a task when people believe or think they can successfully accomplish the task. Further, people with a high level of self-efficacy tend to learn more from training and also tend to use what they have learned to enhance job performance.

Many previous studies have revealed that self-efficacy beliefs are related to learning outcomes. For example, Yildirim et al. (n.d.) studied the relationship between learner outcomes and self-efficacy beliefs. Subjects were fifty sophomores and seventeen seniors who were studying industrial engineering at the University of Pittsburgh. Three to four participants were given Model Eliciting Activities (MEA) to solve. Participants were required to solve specific MEA problems and rate how well they believed they did on each question. The goal was to analyze the level of modeling and problem-solving skills, as well as to measure the self-efficacy beliefs of participants. The research results showed that a significant correlation existed between self-efficacy beliefs and performance.

As part of the study, anonymous peer reviews were automatically received for each learner’s homework and sent back to the student through a system, called a research-networked portfolio system. Learners were required to revise homework based on the peer reviews and complete questionnaires through the same system. The research results supported Bandura's (1997) proposition that self-efficacy beliefs can develop through social persuasion. The results showed that learners with high levels of self-efficacy beliefs will apply higher-level learning strategies, such as elaboration and critical thinking, compared with students who have lower levels of self-efficacy beliefs.

Similarly, in 2009, Isman and Celikli studied the impact of self-efficacy beliefs and analyzed learner beliefs towards the use of computer technology. The study included 70 undergraduate students from the Eastern Mediterranean University's Faculty of Education. Approximately 36 participants were from the English Language Teaching Department, and 34 participants were from the Turkish Language Teaching Department. Survey questions were used to measure individual self-efficacy levels. Data on past experience, gender, and department were also collected. The researchers found that the number of years participants used the computer had an impact on self-efficacy beliefs. Specifically, the study showed that participants who had experience using a computer for four years or more had higher confidence in their computer skills compared with a group of participants who had used the computer for less than four years.

Adeyemo (2007) studied the influence of emotional intelligence on academic self-efficacy beliefs and on the achievements of university students. A total of 300 participants participated in the study. Participants were asked to complete a questionnaire using the Academic Confidence Scale (ACS) developed by Sander and

Sander (2007). The results showed a significant relationship between academic achievement and academic self-efficacy beliefs. Adeyemo found that self-efficacy beliefs were positively related to academic achievement.

Mahyuddin et al. (2006) explored the relationship between self-efficacy beliefs and English language acquisition. A total of 1,146 participants from eight secondary schools participated in this study. The participants came from different countries, including Malaysia, China, and India. The objectives of this study were focused on four areas: 1) measuring the level of self-efficacy beliefs related to knowledge of the English language; 2) measuring the difference in the level of self-efficacy beliefs between males and females; 3) measuring the difference in the level of self-efficacy beliefs between urban and rural schools; 4) and measuring the relationship between self-efficacy beliefs and English language acquisition. The self-efficacy beliefs scale developed by Bandura (1995) and Kim and Park (1997) were used to measure participant self-efficacy beliefs. The results showed that about 55 percent of participants had high self-efficacy beliefs and 49 percent had low self-efficacy beliefs related to knowledge of the English language. A total of 44 percent of those people with low self-efficacy beliefs related to knowledge of the English language believed that English was difficult for them, which resulted in lower motivation to learn. Moreover, researchers found that there was a relationship between self-efficacy beliefs and measured learning achievements. The results indicated that participants with higher levels of self-efficacy beliefs demonstrated better performance when compared to those with lower levels of self-efficacy beliefs.

Lorsbach and Jinks (1999) studied the impact of self-efficacy beliefs on learning environments. The researchers concluded that individual self-efficacy beliefs regarding academic performance are an important key to improving learning environments and to improving learner outcomes. The authors suggested that understanding the concept of academic self-efficacy beliefs aids in understanding what is happening in the classroom and helps educators, instructors, and students improve the learning environment. Zimmerman and Kitsantas (2005) studied whether learner self-efficacy beliefs for learning and perceived responsibility beliefs affected homework practices and grade point average. A total of 179 high school girls participated in the study. A survey was administered during a regular class period at the beginning of the second quarter in the school year. The survey included 86 items in four areas: personal data questions, homework survey, self-efficacy beliefs, and perceived responsibility for learning. The results indicated found that homework practices significantly predicted learner self-efficacy beliefs, learning outcomes, and perceptions of responsibility for learning. Learner self-efficacy beliefs and perceptions of responsibility for learning were found to play an important role in both learner homework practices and GPA.

To date, many researchers have found that individual self-efficacy beliefs and attitudes are significant, influential factors in academic achievement and work performance. Moreover, previous studies have identified the importance of learner attitudes in learning achievement and performance. Improved learner attitude should have a positive influence on the achievement of learning goals. The role of learner attitudes on learning, based on previous research, is discussed next.

7.4 **Attitudes**

Studies of learner attitudes, specifically towards simulation are limited. However, previous studies have identified that one of the major uses of simulation is to increase and change the attitudes of participants (Bordon, 1970, p.166) towards a particular topic. Attitudes are an important factor that educators and researchers can use to understand and predict people's reactions to objects or changes (Ajzen & Fishbein, 1975). Gardner (1985, p.9) defined an individual's attitude as "an evaluative reaction to some referent, inferred on the basis of the individual's beliefs or opinions about the referents. Two attitudes explored in the literature related to learning are motivation and enjoyment. According to Mullins (1996) motivation is "the driving force within individuals by which they attempt to achieve some goal in order to fulfill some need or expectation." Bomia et al. (1997, p.1) defined motivation as, "a student's willingness, need, desire, and compulsion to participate in, and be successful in, the learning process," Motivation has been found to be positively correlated with learning skills and academic achievement.

Three types of motivation defined in the literature are intrinsic goal orientation, extrinsic goal orientation, and task value. Intrinsic goal orientation refers to the degree to which one perceives his/herself to be participating in a task because the task itself is perceived as challenging and arouses curiosity. Extrinsic goal orientation refers to degree to which one perceives his/herself to be participating in a task because the task itself is connected with a desired external condition, e.g. a high course grade, a reward, or a course credit. Task value refers to degree to which one perceives his/herself to be participating in a task because the task itself is perceived as important.

Many studies have found significant relationships between learner attitudes and learning. For example, Luckie et al. (2004) argued that a significant and positive improvement in attitudes toward the learning experience might lead to higher achievement. Prokop et al. (2007) studied the relationship between student knowledge and attitudes toward biotechnology. A total of 378 students participated in the study. Students completed two surveys including a biotechnology attitude questionnaire and a biotechnology knowledge questionnaire. The results found a significant positive correlation between attitudes and the level of individual knowledge. Similarly, Gottfried (1980) examined the relationship between academic intrinsic motivation and academic achievement. The research results showed that academic intrinsic motivation was positively related to academic achievement and IQ. The results indicated that a decrease in academic intrinsic motivation might lead to a significant decrease in academic achievement.

Other studies have found a significant relationship between knowledge, attitudes, and achievement (DiEnno & Hilton, 2005; Sorge & Schau, 2002). For example, Depaola and Mclaren (2006) investigated the relationship between learner attitudes and performance in statistics and calculus. The study included 229 participants. Data were collected from individual records, performance on in-class exams, and three surveys. Surveys were used to measure student experiences with math and current attitudes toward math and calculus classes. The results found that individuals developed more positive attitudes during the class; however, learners had less positive attitudes towards calculus than statistics. The study results also indicated that learners who earned lower exam scores showed negative attitudes toward statistics and calculus. Depaola and Mclaren (2006) also found that learners who did not have a background in calculus did poorly on the exam and held strong negative attitudes toward calculus.

Similarly, Lin et al. (2001) studied the influence of extrinsic and intrinsic motivation on learning. A total of 650 participants were recruited from college students in 13 classes, such as biology and psychology at the University of Michigan, Alma College, Washtenaw Community College, Eastern Michigan University, and Keimyung University in Korea. The scores of both intrinsic and extrinsic motivation scales were divided into low, medium, and high levels. Items on the Motivated Strategies for Learning Questionnaire (MSLQ) were scored using a five-point Likert scale. The results indicated that learners who have high levels of intrinsic motivation and medium levels of extrinsic motivation seem to receive higher mean course grades than students with either low or high extrinsic motivation. Another study by Eccles et al. (1983) and Eccles (2005) highlighted the importance of learner task value as a positive predictor of intentions and decisions to continuously take mathematics and English classes. Individual enjoyment has also been associated with higher degrees of motivation, learning, and learning outcome achievement.

Moreover, studies have found positive relationships between learner enjoyment and learning outcomes. For example, Blunsdon et al. (2003) found that enjoyment had a positive impact on improving learner perceptions and increasing learning outcome achievement. In contrast, Rieber and Nach (2008) studied the impact of game-like activities on adult learning during a computer-based simulation. The research found no correlation between enjoyment and learning outcome achievement. The study revealed that the fun and enjoyment resulting from playing the game disrupted student learning. Although some research showed that enjoyment has been found to be positively related to learner desire to continue learning, other studies have not supported this relationship. As a result there are still many questions to be answered about the effect of learner enjoyment on learning and performance.

Therefore, the purpose of this study was to explore the effects of the use of collaborative and simulation teaching techniques on self-efficacy beliefs and attitudes. The investigation focused on the use of collaborative and simulation teaching techniques in higher education settings. In this study, two non-traditional teaching techniques (collaborative and simulation) were evaluated. Collaborative sessions consisted of both lectures and some type of in class activity. Simulation in this study was defined as live simulations. The following research hypotheses were developed: 1) collaborative and/or simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy survey socres 2) collaborative and/or simulation sessions do not affect attitudes as measured by learner motivation and enjoyment survey scores. The research methods used to explore these hypotheses are described next.

7.5 **Methods**

7.5.1 **Participants**

One hundred fifty-five undergraduate students from three universities (University of Pittsburgh, Worcester Polytechnic Institute, and Oakland University's Pawley Lean Institute) participated in the study, but only eighty-two with matched survey data were used. A recruitment letter or email was sent to instructors who planned to teach lean manufacturing systems or related courses on lean principles and methods. The hardcopy surveys and consent form were sent by post to instructor(s) after the instructor(s) agreed to participate in the study.

7.5.2 **Lean or Related Lean Course Description**

The lean principles and methods or related courses generally utilized both collaborative and simulation sessions. The collaborative sessions consisted of traditional teaching methods (lectures, Powerpoint presentation, and case study) and in-class activities. The three universities (University of Pittsburgh, Worcester Polytechnic Institute, and Oakland University's Pawley Lean Institute) had different course formatting. For example, learners from the University of Pittsburgh studied through simulation sessions, followed by lectures and some in-class activities; whereas, the other two universities (Worcester Polytechnic Institute, and Oakland University's Pawley Lean Institute) provided students with collaborative sessions and then simulation sessions. Three in-class activities and two different simulation activities were used as shown in Table 40. More detailed information on the two simulations used in the universities is described next.

Table 40: Participant universities, collaborative activities, and simulation activities

Universities	Collaborative activities	Simulation activities
University of Pittsburgh	The activity used demonstrated the concepts of work in process, throughput, cycle time, and inventory in a penny production line.	TimeWise Simulation
Worcester Polytechnic Institute	A Dice Game was used to explore push and pull systems.	TimeWise Simulation
Oakland University's Pawley Lean Institute	A paper cup exercise was used to illustrate pull and other lean concepts.	MouseTrap simulation (also called The MouseTrap Exercise)

The TimeWise Simulation, used by two of the universities, is aimed to help learners gain a better understanding of lean principles and methods using a simulated clock assembly. Role-playing techniques are used and provide an opportunity for learners to practice lean methods in this physical clock assembly environment. The TimeWise Simulation allows learners to experience the benefits and challenges of using traditional and lean manufacturing systems approaches. Moreover, it allows participants to work as a team. Learners are given a specific role in the simulated clock assembly line, such as assembly operator or support personnel. Participants work as a group to assemble two clocks: a blue clock and a black clock.

The TimeWise simulation consists of four rounds. Participants experience traditional manufacturing processes in the first round and learn to apply lean manufacturing principles and methods during the second, third, and fourth rounds. Each round takes approximately 15 minutes to complete and is followed by a five-to-ten minute discussion. The TimeWise simulation allows participants the opportunity to integrate learning process by doing and also enhances participants ability to see how lean principles and methods can be used and applied in manufacturing environments. Several lean principles and methods are presented at various points in the simulation, including pull production, poka-yoke, 5S, and visual workplace techniques.

Oakland University's Pawley Lean Institute offers a lean principles and practices class for undergraduates that meets for over three hours once a week. The class uses a simulation called the MouseTrap simulation to demonstrate the differences between mass and batch production. The simulation begins with a lecture on lean principles and then has participants use the plan/do/check/act (PDCA) method to implement an improved production system. Three to five learners are in each group. The MouseTrap simulation takes approximately three hours. The MouseTrap simulation is run three times. In each round, learners or players are allowed to change only two things in order to achieve production goals. The MouseTrap simulation covers the concepts of standardization, Kanban, and PDCA. Photographs of the MouseTrap simulation are shown in Figure 23.

Figure 23: Sample of MouseTrap simulation

7.5.3 **Procedures and Instruments**

Two sets of surveys were distributed to participants to measure two areas of learner perceptions towards the use of collaborative and /or simulation sessions. Each survey contained items to measure self-efficacy beliefs and attitudes. Each university received the survey at different times depending on the course schedule. Additionally, each survey consisted of nearly identical questions, which asked participants to indicate their degree of agreement or disagreement on the different type of session used for teaching and training lean principles and methods.

Self-efficacy beliefs were used to evaluate learner's levels of confidence in their ability to learn and apply lean principles and methods after participating collaborative and simulation sessions. To assess the level of self-efficacy beliefs, six items related to learner self-efficacy beliefs were developed. Participants responded to survey items using a 5-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). Table 41 lists the survey items used to measure learner self-efficacy beliefs.

Table 41: Survey items used to measure learner self-efficacy beliefs

Survey variables	Item Content
Self-efficacy beliefs	• As a result of [Type of session]*, I believe that I will be able to respond to exam questions on lean manufacturing. • The [type of session]* increased my confidence in my own understanding of lean manufacturing principles. • I am certain I understand the most difficult principles used in the [type of session]. • As a result of [type of session]*, I have no doubt about my capability to do well on lean manufacturing assignments. • As a result of [type of session]*, I can now explain to my friends what I have learned about lean manufacturing. • I am certain I can master the skills being taught in the [type of session]*.

Note: the phrase, “type of session,” was replaced with a particular type of session e.g.: collaborative or simulation session.

Attitudes were defined as the way learners think, feel, and react as a result of learning lean principles and methods from collaborative sessions and/or simulation sessions. Four constructs (intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment) were used to evaluate learner attitudes. Intrinsic goal orientation refers to a learner’s decision to participate in a task or activity because of a desire to satisfy his/her curiosity and because he/she finds the task to be interesting and challenging. On the other hand, extrinsic goal orientation can be defined as a learner’s decision to engage in a task because of the task itself is connected with a desired external motivator, e.g., a high course grade, a reward, or course credit. Task value refers to learner's decision to engage because the task is important and useful (Pintrich et al., 1991). Finally, enjoyment can be defined as a measure of whether the task itself is pleasurable and enjoyable (Pekrun et al, 2002)

The attitude section of the survey consisted of 16 items, with four items for each of the four constructs: intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment. Participants were asked to rate their level of agreement with these 16 items using a five-point Likert scale (1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree). Table 42 lists the survey items used to measure learner attitudes.

Table 42: Survey items used to measure learner attitudes

Survey variables	Item content
Intrinsic goal orientation	• I prefer [type of session] that are challenging so I can learn new things. • I prefer [type of session] that arouses my curiosity, even they are difficult. • I prefer [type of session] that I will learn something from even if they require more work. • I prefer [type of session] that I can learn something from even if they do not guarantee a good grade.
Extrinsic goal orientation	• Learning from [type of session] helps prepare me for tests. • Learning from [type of session] helps me get good grade on tests. • I participate in [type of session] because I am supposed to. • I prefer [type of session] because I am sure I can do them.
Task value	• As a result of [type of session], I believe that I will able to use what I have learned in other courses. • It is important for me to learn what is taught in [type of session]. • I think that what I have learned from [type of session] is useful for me to know. • As a result of [type of session], I believe that I can apply what I have learned to real-world problems.
Enjoyment	• I enjoy participating in [type of session]. • I feel that time flies when I participate in [type of session]. • After finishing [type of session], I look forward to the next class. • I would like to spend more time on [type of session].

Note: the phrase, “type of session,” was replaced with a particular type of session e.g.: collaborative or simulation session.

7.6 **Results**

SPSS IBM 19.0 was used to complete all analyses. Cronbach’s alpha for each set of survey items was calculated to check the internal reliability of each construct. The Cronbach’s alpha coefficients for each construct are summarized in Table 43.

Table 43: Reliability of each research construct

Research Construct	Number of Item	Cronbach's Alpha
Self-efficacy beliefs on lean after collaborative sessions	6	0.81[1] 0.87[2] 0.81[3]
Self-efficacy beliefs on lean after simulation sessions	6	0.77[1] 0.92[2] 0.69[3]
Motivation after collaborative sessions	12	0.71[1] 0.86[2] 0.86[3]
Motivation after simulation sessions	12	0.76[1] 0.92[2] 0.90[3]
Enjoyment after collaborative sessions	4	0.88[1] 0.90[2] 0.79[3]
Enjoyment after simulation sessions	4	0.81[1] 0.96[2] 0.83[3]

Note: "1" refers to University of Pittsburgh, "2" refers to Worcester Polytechnic Institute, and "3" refers to Oakland University's Pawley Lean Institute

All constructs had a Cronbach's alpha coefficient greater than 0.65, and most constructs were greater than 0.75. Nunnally (1978) and Garson (2010) stated that a Cronbach's alpha coefficient greater than 0.7 is considered satisfactory; whereas, a coefficient of 0.5 or above is considered acceptable. For this reason, the constructs for this study were considered to be reliable.

Q-Q plots were created and reviewed to determine whether or not the data were normally distributed. The Q-Q plots for all research variables measured for this study are shown in Figure 24. Descriptive statistics and parametric tests (e.g. paired t-tests and linear regression) were used to test all research hypotheses questions. A p-value of 0.05 was used to identify statistically significant relationships for all analyses.

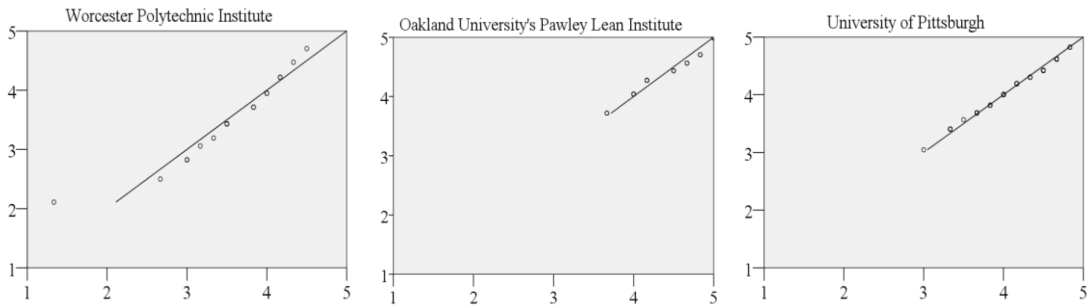

Figure 24: Q-Q plots for self-efficacy beliefs variable by university

Mean scores were calculated for each research variable, including self-efficacy beliefs and attitudes. Paired t-tests analyses were used to investigate whether any differences existed in learner self-efficacy beliefs and/or learner attitudes (intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment) following the use of collaborative and simulation sessions.

As shown in Table 44, significant differences were only found in learner self-efficacy beliefs for two universities: the University of Pittsburgh and Worcester Polytechnic Institute, between the use of simulation sessions and collaborative sessions or the use of collaborative sessions and simulation sessions, respectively. However, no statistically significant differences were found in learner self-efficacy beliefs for participants from Oakland University’s Pawley Lean Institute. Interestingly, participants from the University of Pittsburgh who participated in simulation sessions first and collaborative sessions second appeared to show slightly decreased levels of self-efficacy beliefs in learning and applying lean principles and methods. Figure 25 summarizes the data using boxplots of the learner self-efficacy beliefs for each university.

Table 44: Mean scores and paired t-test results for self-efficacy after participating in collaborative and simulation sessions

Self-efficacy beliefs	n	Mean			*p*-value
		Survey 1	Survey 2	Paired t-test statistic	
University of Pittsburgh	46	4.15[2]	3.89[1]	0.26	**0.007**
Worcester Polytechnic Institute	18	3.60[1]	3.91[2]	-0.31	**0.048**
Oakland University's Pawley Lean Institute	18	4.44[1]	4.51[2]	-0.07	0.505

Note: "1" refers to collaborative sessions and "2" refers to simulation sessions

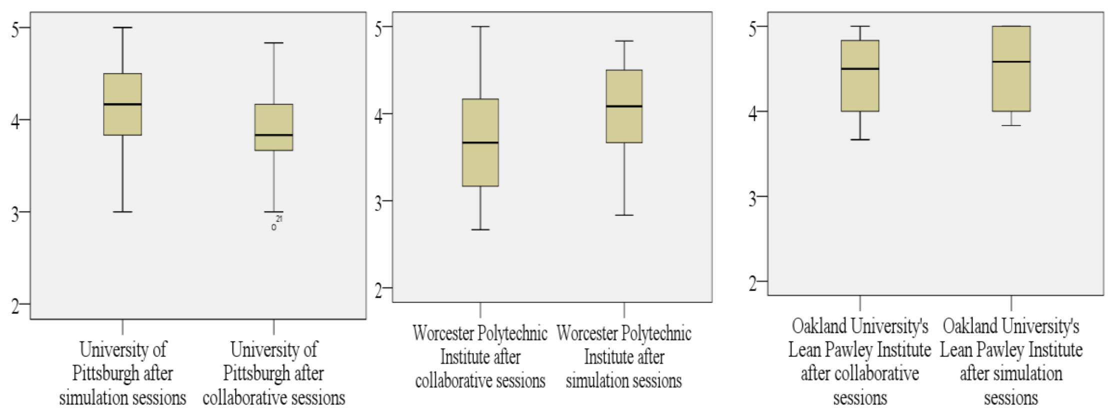

Figure 25: Box plots comparing self-efficacy beliefs before and/or after simulation and collaborative sessions for each university.

Next, Q-Q plots of learner attitudes were reviewed. The Q-Q plots indicate that the data appear to be approximately normally distributed (see Figure 26), thus parametric techniques were used for all analyses.

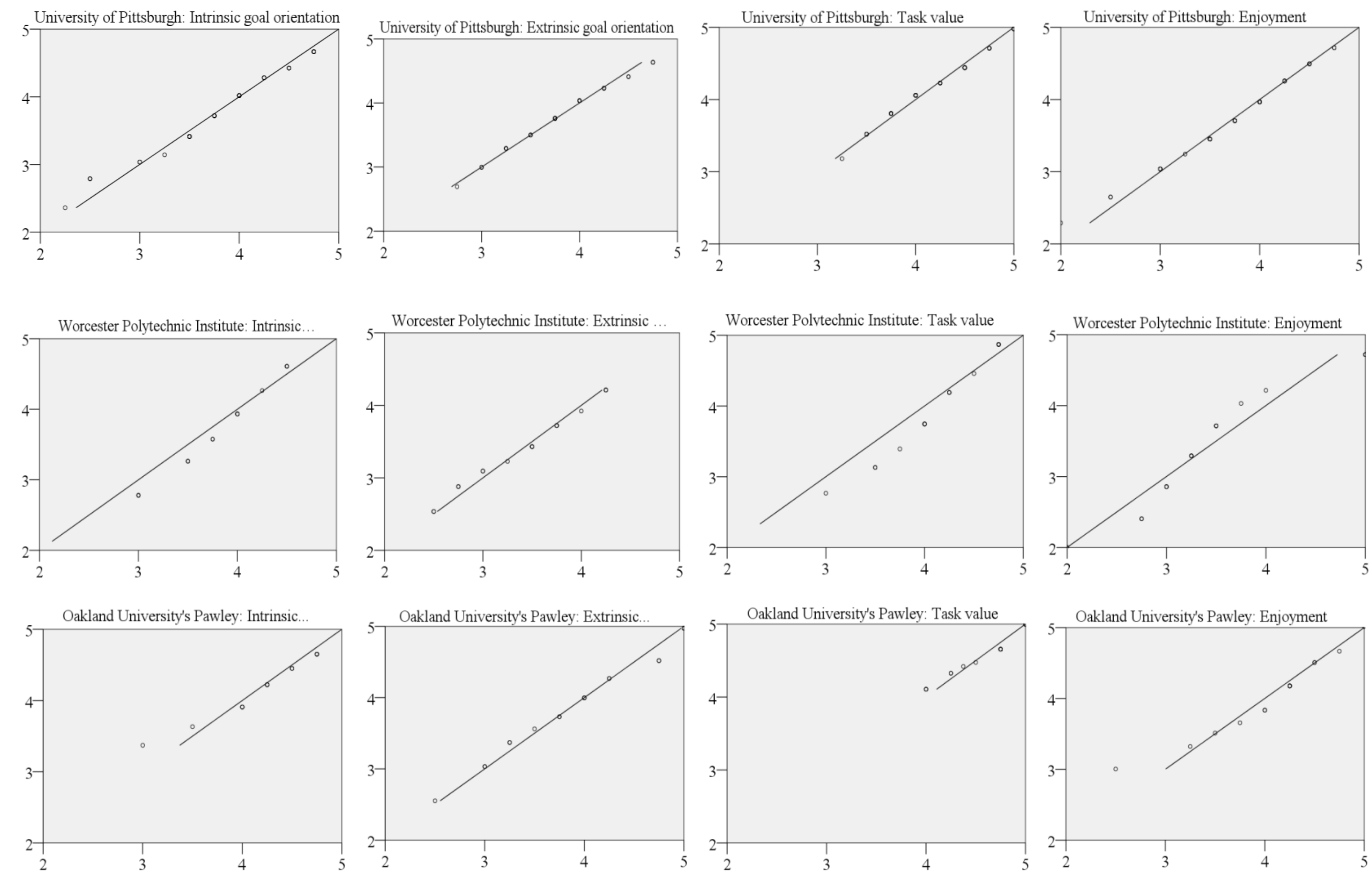

Figure 26: Q-Q plots for each attitude

As shown in Table 45, only participants from Worcester Polytechnic Institute exhibited statistically significance differences in intrinsic motivation. Figure 27 shows a boxplot of learner intrinsic goal orientation for each university.

Table 45: Mean scores and paired t-test results for learner intrinsic goal orientation after participating in collaborative and simulation sessions

Intrinsic Goal Orientation	n	Mean Survey 1	Mean Survey 2	Paired t-tests Statistic	Sig. (2-tailed)
University of Pittsburgh	46	3.84^2	3.86^1	-0.02	0.802
Worcester Polytechnic Institute	18	3.70^1	3.99^2	-0.29	**0.013**
Oakland University's Pawley Lean Institute	18	4.38^1	4.33^2	0.05	0.820

Note: "1" refers to collaborative sessions and "2" refers to simulation sessions

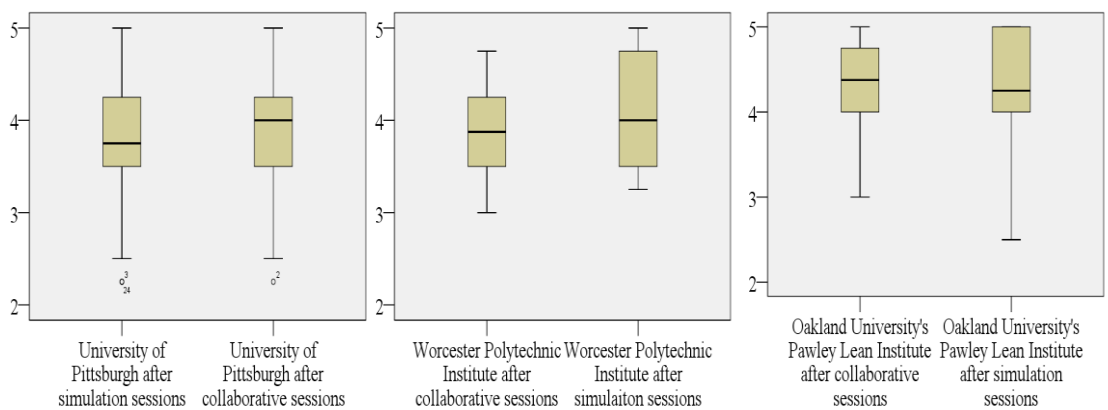

Figure 27: Box plots comparing learner intrinsic goal orientation before and/or after simulation and collaborative sessions for each university.

As shown in Table 46, significant differences in learner extrinsic goal orientation were found for participants from all three universities. For universities where collaborative sessions were used first, followed by simulation sessions, the findings revealed that learner extrinsic motivation level increased after participating in simulation sessions. On the other hand, for the University of Pittsburgh, the findings revealed that learner extrinsic motivation decreased after participating in collaborative sessions. Figure 28 shows a boxplot of learner extrinsic goal orientation for each university.

Table 46: Mean scores and paired t-test results for learner extrinsic goal orientation after participating in collaborative and simulation sessions

Extrinsic Goal Orientation	n	Mean			Sig. (2-tailed)
		Survey 1	Survey 2	Paired t-tests Statistic	
University of Pittsburgh	46	3.93[2]	3.76[1]	0.17	**0.033**
Worcester Polytechnic Institute	18	3.86[1]	4.28[2]	-0.42	**0.016**
Oakland University’s Pawley Lean Institute	18	3.94[1]	4.14[2]	-0.2	**0.005**

Note: “1” refers to collaborative and “2” refers to simulation

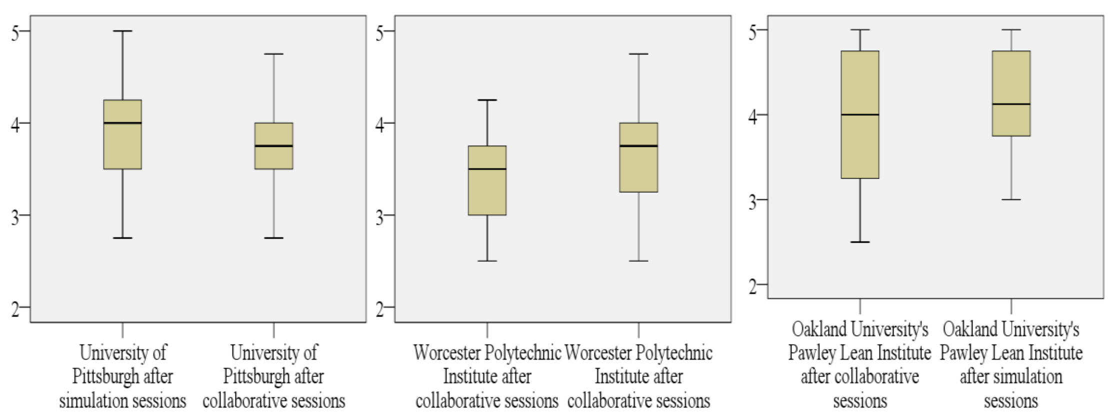

Figure 28: Box plots comparing extrinsic goal orientation before and/or after simulation for each university.

As shown in Table 47, the paired t-test results showed only participants from the University of Pittsburgh had statistically significance differences in task value. Figure 29 shows a boxplot of learner task value for each university.

Table 47 : Mean scores and paired t-test results for learner task value after participating in collaborative and simulation sessions

Task value	n	Mean			Sig. (2-tailed)
		Survey 1	Survey 2	Paired t-tests Statistic	
University of Pittsburgh	46	4.23^{2}	4.42^{1}	-0.19	**0.009**
Worcester Polytechnic Institute	18	4.00^{1}	4.04^{2}	-0.04	0.108
Oakland University's Pawley Lean Institute	18	4.60^{1}	4.59^{2}	0.01	0.901

Note: "1" refers to collaborative sessions and "2" refers to simulation sessions

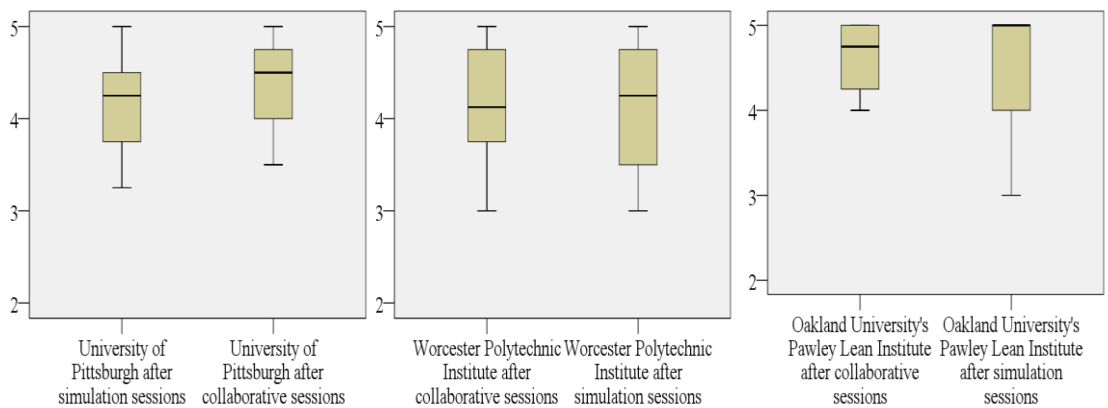

Figure 29: Box plots comparing task value before and/or after simulation for each university.

As shown in Table 48, the paired t-test results showed no significant differences in learner enjoyment for participants from any of the three universities. Figure 30 shows a boxplot of enjoyment for each university. A discussion and conclusions resulting from this research are provided next.

Table 48: Mean scores and paired t-test results for learner enjoyment after participating in collaborative and simulation sessions

Enjoyment	n	Mean			Sig. (2-tailed)
		Survey 1	Survey 2	Paired t-tests Statistic	
University of Pittsburgh	46	3.71[2]	3.80[1]	-0.09	0.464
Worcester Polytechnic Institute	18	3.40[1]	3.92[2]	-0.52	0.644
Oakland University's Pawley Lean Institute	18	4.22[1]	4.51[2]	-0.29	0.176

Note: "1" refers to collaborative sessions and "2" refers to simulation sessions

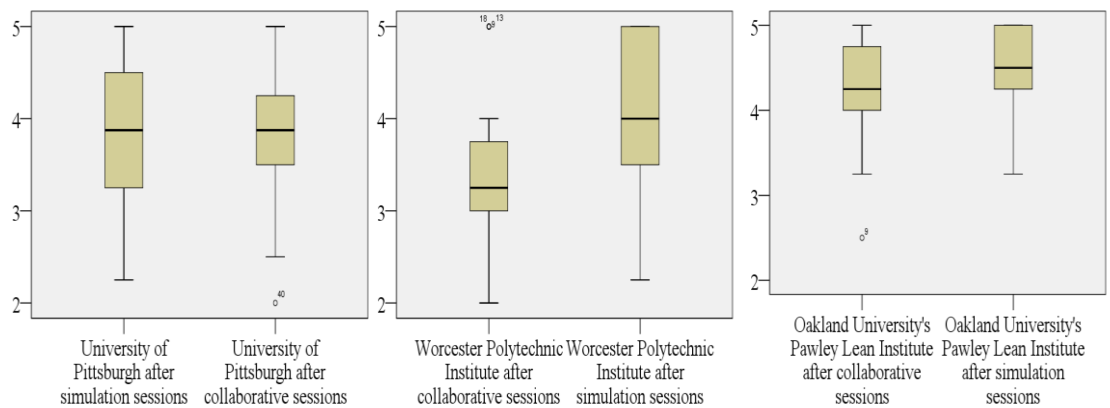

Figure 30: Box plots comparing enjoyment before and/or after simulation for each university.

Table 49 summaries of all research questions and major findings from this research study. Positive and significant relationships are depicted as a "+," whereas, negative and non-significant relationships are depicted using a "-" or "0," respectively.

Table 49: Summary of research questions and major findings.

Research Questions	University	Findings
Collaborative and/or simulation sessions do not affect self-efficacy beliefs as measured by self-efficacy survey scores.	University of Pittsburgh	-
	Worcester Polytechnic Institute	+
	Oakland University's Pawley Lean Institute	0
Collaborative and/or simulation sessions do not affect attitudes (intrinsic goal orientation) as measured by learner motivation and enjoyment survey scores.	University of Pittsburgh	0
	Worcester Polytechnic Institute	+
	Oakland University's Pawley Lean Institute	0
Collaborative and/or simulation sessions do not affect attitudes as measured (extrinsic goal orientation) by learner motivation and enjoyment survey scores.	University of Pittsburgh	-
	Worcester Polytechnic Institute	+
	Oakland University's Pawley Lean Institute	+
Collaborative and/or simulation sessions do not affect attitudes as measured (task value) by learner motivation and enjoyment survey scores.	University of Pittsburgh	+
	Worcester Polytechnic Institute	0
	Oakland University's Pawley Lean Institute	0
Collaborative and/or simulation sessions do not affect attitudes (enjoyment) as measured by learner motivation and enjoyment survey scores.	University of Pittsburgh	0
	Worcester Polytechnic Institute	0
	Oakland University's Pawley Lean Institute	0

7.7 **Discussion and Conclusions**

This study investigated the impact of nontraditional teaching methods, including collaborative and simulation sessions, on learner self-efficacy beliefs and attitudes (intrinsic goal orientation, extrinsic goal orientation, task value, enjoyment). Overall, the findings show some significant differences between the use of these types of sessions on learner self-efficacy, intrinsic goal orientation, extrinsic goal orientation, and task value. The research findings are discussed next.

A comparison of self-efficacy beliefs showed some statistically significant results. The results of a paired t-test found that for universities where simulation sessions were used first, followed by collaborative sessions, learner levels of self-efficacy decreased. In contrast, the universities where collaborative sessions were used, followed by simulation sessions, showed different results. There was no difference between learner self-efficacy before and after the simulation sessions for participants from Oakland University's Pawley Lean Institute; however, significant differences were found in participants from Worcester Polytechnic Institute. Although the findings were inconclusive, overall research results seem to indicate some positive value from the use of simulation sessions for improving learner self-efficacy beliefs. Findings from the analysis showed that mean scores on learner self-efficacy beliefs from before and after simulation had slightly increased, which may indicate the use of simulation sessions improved learner self-efficacy in learning and applying lean principles and methods. These results are consistent with findings in previous studies conducted in educational settings, where simulation has a positive influence for improving learner self-efficacy (Goldenberg et al., 2005; Pike & O'Donnell, 2010). The study also found that participants who attended simulation first and then collaborative sessions had slightly decreased self-efficacy mean scores. It appears that the sequence of using non-traditional teaching sessions (collaborative and simulation sessions) when learning lean principles and methods has some influence on learner self-efficacy beliefs. Future research should continue to investigate the impact of the sequencing of non-traditional teaching sessions on learner self-efficacy beliefs.

This study investigated the impact of collaborative and/or simulation sessions for teaching lean principles and methods on learner attitudes (intrinsic goal orientation, extrinsic goal orientation, task value, and enjoyment). First, the effect of the use of collaborative and/or simulation sessions on learner intrinsic goal orientation, showed significant differences for only one university, Worcester Polytechnic Institute. A increase in intrinsic goal orientation was observed when participants observed lean through collaborative sessions first and followed by simulation sessions. However, overall, these research findings revealed no difference in learner intrinsic goal motivation between the use of collaborative and simulation sessions for teaching lean principles and methods. The findings may indicate that the use of both types of sessions can encourage learners to participate in the learning sessions because they find the sessions challenging and interesting. Future research may need to identify whether the type of session influences learner intrinsic goal orientation by measuring learner intrinsic goal orientation before each type of session. Previous studies have shown a positive relationship between intrinsic goal orientation for school learning and academic success (Karsenti & Thibert, 1995).

Second, the findings showed a difference in learner extrinsic goal motivation levels for all three universities and a increase, regardless of the ordering of the sessions. Learner extrinsic goal motivation levels could be related to other learner work, for example, assignment scores during each type of session. Future research could focus on learner work, such as assignment scores, which could provide more information to help assess learner extrinsic goal orientation.

Third, the findings revealed that only participants at the University of Pittsburgh showed a significant difference in task value. The findings showed that learner task value increased when participants participated in simulation sessions first, followed by collaborative sessions. Although the findings did not show significant learner task value improvement after participating in simulation sessions, overall, learners commented that the application of topics covered through lean simulation makes lectures more useful. This could indicate that the use of collaborative and/or simulation sessions as a supplementary teaching tool helps learners believe that learning lean will be meaningful. Future research is needed to explore whether the sequencing of non-traditional teaching sessions is another factor in learner task value.

Lastly, no differences were found in level of enjoyment despite the differences in session type or sequence. The findings also showed that learner enjoyment remained moderate to high for both types of sessions. These findings indicated that both types of sessions (collaborative and simulation sessions) did not affect learner enjoyment. Given the high overall averages, learners felt both types of sessions were fun and enjoyable. These results are consistent with previous studies that found activities or games promote learner enjoyment. For example, Rose (2011) developed a board game designed to promote student learning and improve student enjoyment for pharmacy students learning metabolic pathway. The result showed that learning through the board game engaged students to learn the subject and was enjoyable (Rose, 2011).

The research has some limitations. One of its limitations is that the research only examines learner perceptions (self-efficacy beliefs and attitudes) after collaborative sessions and after simulation sessions. Future research should determine learner perceptions prior to each type of session in order to draw broader implications about whether each type of session influences learner perceptions (self-efficacy beliefs and attitudes). Another limitation is the study's natural setting, a real classroom with volunteer participants. The scope of this research was limited to only measuring learner self-efficacy beliefs and attitudes. Future research on academic achievement is recommended.

7.8 **Contribution**

The outcomes of this research has direct implications for lean educators and provides some guidelines for lean educators to better understand how to teach lean principles and methods in order to maximize learner perceptions. The findings of this research provide evidence that using collaborative sessions, followed by simulation sessions is an effective means to improve self-efficacy beliefs and some learner attitudes. It is important for lean educators to consider the sequencing of non-traditional teaching methods as another factor that affects learner self-efficacy beliefs. Thus, lean educators should be aware that the sequence of non-traditional techniques may impact learner self-efficacy beliefs.

The overall results proved that the use of collaborative and simulation sessions in learning lean principles and methods impacts learner extrinsic goal orientation. Learner extrinsic goal motivation increased when participants participated in collaborative sessions, followed by simulation sessions. In this case, the sequencing of non-traditional teaching sessions may influence learner extrinsic goal orientation.

In addition, the overall findings showed that the use of both types of sessions (collaborative and simulation sessions) did not result in measureable differences in overall learner attitudes (intrinsic goal, task value, and enjoyment). Moreover, the findings of this research reveal that the sequencing of non-traditional teaching techniques (collaborative and simulation sessions) also appears to be important factor in learner extrinsic goal orientation. Even though the use of collaborative and simulation sessions did not improve overall learner attitudes, the results confirm that these types of sessions can be implemented successfully in lean courses. The mean scores for learner attitudes generally indicated that learners were responding positively to both types of sessions.

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8. Summary, Discussion, and Conclusions

This chapter draws together relevant research findings from the multiple papers presented. This chapter begins with a summary of the complete set of research findings, including the results from both participants groups. The contributions of this research study and recommendations for future research are also provided.

8.1 Research Findings

A set of research hypotheses were used for two different studies, study one (chapter 6) and study two (chapter 7). Participants from group one were used for first study and participants from group two were used for second study. Participants from group one were undergraduate and graduate students from Oregon State University; whereas, participants from group two were undergraduate students from three universities (University of Pittsburgh, Worcester Polytechnic Institute, and Oakland University's Pawley Lean Institute. In the first study, data were used to investigate the impact of the use of collaborative and simulation sessions on learning and learner perceptions, self-efficacy beliefs and attitudes when learning lean principles and methods. On the other hand, in the second study, data were used to investigate the impact of the use of collaborative and simulation sessions on learner perceptions, self-efficacy beliefs and attitudes when learning lean principles and methods.

In this section, the findings are presented in three parts. The first part is focused on studying the effects of the use of collaborative and simulation sessions on each major focus area: learning, self-efficacy beliefs, and attitudes when learning and training lean principles and methods. The second part is aimed at determining the effect of differences in lean background knowledge on learning, self-efficacy beliefs, and attitudes. The third part examines the relationship between type of session, background knowledge, and self-efficacy beliefs in learning and attitudes resulting from collaborative and simulation sessions.

8.1.1 **Learning**

The first research questions addressed in this research study were developed 1) to study the impact of collaborative sessions on learning; 2) to study the impact of simulation sessions on learning; and 3) to study the impact of the type of session on learning. Data from participants in group one, participants from Oregon State University, were used. First, the results showed that the mean scores of knowledge tests on Jidoka and pull methods increased after participating in collaborative sessions. The findings indicated that collaborative sessions, when used for Jidoka and pull methods, have a significant influence on participant learning. The results of this study reveal the benefit of the use of collaborative session on learning, especially Jidoka and pull methods. Second, Jidoka content knowledge was shown to increase after participating in simulation sessions. It is interesting to note the overall average content knowledge test scores on pull methods before and after participating in collaborative sessions and/or simulation sessions were relatively high (scores of approximately 7 out of 10). Third, the mean gain scores in knowledge of Jidoka and pull methods were significantly different only when pull methods were observed. The study results indicated that the content area is a factor in determining the impact of collaborative or simulation sessions on learning. Future research studies should investigate the impact of collaborative and simulation sessions on other lean content areas.

8.1.2 **Self-efficacy Beliefs**

The second set of research questions addressed in this study investigated the impact of the use of simulation, after collaborative sessions, on learner self-efficacy beliefs. Two groups of participants were used for this set of questions. For participants from group one, Oregon State University, the findings showed that there was only a statistically significant difference in self-efficacy beliefs survey scores for pull observed during Fall 2010.

In contrast, simulation sessions had a mixed effect on self-efficacy beliefs for participants in group two, where instructors at two universities provided learners with collaborative sessions and then simulation sessions. Moreover, significant differences were found in self-efficacy for participants from the University of Pittsburgh, where learners experienced simulation sessions first, followed by collaborative sessions. Surprisingly, the findings from participants in group two showed that the sequence of the use of non-traditional teaching methods influenced changes in learner self-efficacy beliefs. The results showed that participants from universities in which learners participated in collaborative sessions first, followed by simulation sessions, had a slightly higher level of self-efficacy beliefs; whereas, self-efficacy beliefs decreased slightly at the university where simulation sessions were used first, followed by collaborative sessions. The overall results indicated that there were no significant differences in learner self-efficacy beliefs after participating in simulation sessions. The study found that the sequence of non-traditional teaching methods used may impact learner self-efficacy beliefs.

8.1.3 **Attitudes**

The third set of research questions addressed in this research study investigated the impact of the use of simulation, after collaborative sessions, on learner attitudes. Two groups of participants were used for this set of questions. For participants in group one, there were significant differences only in learner intrinsic goal motivation when Jidoka methods were taught. On the other hand, the results from group two showed a mixed effect on attitudes after participating in collaborative sessions or simulation sessions. The findings showed a significant increase in learner intrinsic goal motivation only for participants from Worcester Polytechnic Institute. Analysis of learner task value revealed a significant difference for participants from University of Pittsburgh. In addition, there was significant difference in learner extrinsic goal motivation, but not in learner enjoyment for the three universities. The findings indicated that learning through collaborative sessions, followed by simulation, has some impact on learner intrinsic goal orientation. The use of collaborative and simulation sessions have some impact on learner extrinsic goal motivation, but not on learner enjoyment. The sequence of the use of non-traditional teaching methods may influence learner attitudes, especially task value. The impact of non-traditional teaching techniques and the sequence of non-traditional teaching techniques should be studied further as it may influence increases or decreases in learner attitudes.

8.1.4 **Background Knowledge**

The fourth set of research questions addressed in this research study investigated whether or not there was an impact of learner background knowledge on learning and attitudes. Data from participants at Oregon State University were used for this set of questions.

The level of background knowledge had a mixed effect on learning and attitudes. The results showed that the level of background knowledge was found to have a significant impact in learning pull methods only during Fall 2011. Moreover, overall, the level of background knowledge did impact learner intrinsic goal motivation when Jidoka methods were taught, but did not impact other attitudes. The findings indicated that the level of background knowledge may have an influence in learning pull methods and learner intrinsic goal motivation when Jidoka methods were taught.

8.1.5 **Relationships**

The fifth and sixth set of research questions asked whether there is a relationship between type of session, background knowledge, self-efficacy beliefs and learning and attitudes. Participants from Oregon State University were used to answer these questions. Overall, the type of session and background knowledge contributed to learning Jidoka methods; whereas, only background knowledge was found to have a significant relationship in learning pull methods. Moreover, no evidence was found for the relationship between learner self-efficacy beliefs and learning for either lean method (Jidoka and pull). Findings from this study found that the type of session was the best predictor for learning Jidoka; whereas, background knowledge was the predicator for learning pull methods. The multiple regression results strongly support that learner background knowledge is an important factor for successfully learning pull methods. Future research is needed to examine more deeply the relationship between type of session and background knowledge for other lean methods in order to optimize lean learner achievement.

Results of the regression analysis for learner attitudes revealed the overall positive effects of self-efficacy beliefs on some learner attitudes, e.g. extrinsic goal orientation, task value, and enjoyment; whereas, background knowledge was significantly predictive of intrinsic goal orientation for Jidoka methods. The findings of this research study are consistent with the study of Partin et al., (2011) which found the relationship between student self-efficacy beliefs and attitudes towards learning biology. Many studies found self-efficacy beliefs play an important role in increasing academic attitudes and learning. For example, Nicolaidou and Philippou (2004) found a significant relationship between student self-efficacy beliefs in learning mathematics and attitudes, and that self-efficacy beliefs also play an important role in predicting achievement in mathematic problem-solving. When focused on the relationship between type of session, background knowledge, and self-efficacy beliefs, and learning and attitudes, the findings indicated that the level of background knowledge had a mixed effect on learning and on attitudes; whereas, the type of session affected only learning. Moreover, self-efficacy beliefs played a major role in learner attitudes. The content being taught appeared to be an important factor in the impact of the use of collaborative and/or simulation sessions for learning and teaching lean principles and methods. Future research is needed to determine whether there are other factors that affect learning and attitudes.

8.2 **Limitations**

This research study has some limitations. One limitation of this study was the structure of the Oregon State University course used in this research study. The course consisted of traditional teaching methods followed by collaborative session activities, and then simulation sessions. Future research could investigate the influence of the use of collaborative and/or simulation sessions on learning lean principles and methods in universities or courses where only lectures are used. Lastly, learner attitudes and self-efficacy beliefs were measured only after learners participated in both collaborative and simulation sessions. Results from group two participants provide some evidence that the sequence of sessions used may be important in influencing self-efficacy beliefs and attitudes. This study could be extended to measure learner attitudes and self-efficacy beliefs prior to each type of session, as well as following each type of sessions. This would enable a better measure of the effects of using either on both collaborative learning and simulation sessions.

8.3 **Contribution**

The contribution of this research is a clear confirmation that, as shown in the literature, collaborative sessions did positively impact learning. There is also impact from background knowledge, for at least pull methods. Moreover, there is a some relationship between the type of session and background knowledge on learning. The findings provide proof that a complex set of relationships exist. To understand the impact of specific teaching methods on learning, many different factors, including type of session, content areas, sequence of sessions, and background knowledge must be taken into account.

An important implication of the research findings revealed that the content area has an impact on the effect of use of collaborative and/or simulation sessions for learning and teaching lean principles and methods. It would seem that the content area should be considered when selecting and/or applying a particular type of session in higher education settings. A recommendation for future research is to repeat this research study with other lean methods. Further, the findings from group two showed that the sequence of teaching methods influenced learner self-efficacy beliefs. The results showed that participants from universities where learners participated in collaborative sessions first and then simulation sessions held higher levels of self-efficacy beliefs when compared with participants from a university where learners participated in simulation sessions first. Future researchers and lean educators should be aware of the importance of the sequencing of different types of teaching methods for improving academic performance. The results of this study may help lean educators consider the efficacy of non-traditional teaching methods for learning and training lean principles and methods.

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APPENDICES

APPENDIX A: IRB APPROVAL LETTER, IRB PROTOCOL, AND IRB APPLICATION

1) IRB approval letter

OSU Oregon State UNIVERSITY

Institutional Review Board • Office of Research Integrity
B308 Kerr Administration Building, Corvallis, Oregon 97331-2140
Tel 541-737-8008 | Fax 541-737-3093 | IRB@oregonstate.edu
http://oregonstate.edu/research/ori/humansubjects.htm

NOTIFICATION OF EXEMPTION

July 5, 2011

Principal Investigator:	Dr. Toni Doolen	Department:	Mechanical, Industrial, and Manufacturing Engineering
Study Team Members:	N/A		
Student Researcher:	Juthamas Choomlucksana		
Study Number:	4786		
Study Title:	The Impact of Simulation Games in Higher Education Classroom		
Funding Source:	None		
Funding Proposal #:	N/A		
PI on Grant/Contract:	N/A		
Submission Type:	Project Revision received 6/29/2011		
Review Category:	Exempt	Category Number:	1

The above referenced study was reviewed by the OSU Institutional Review Board (IRB) and determined to be exempt from full board review.

Expiration Date: 10/14/2015
The exemption is valid for ***5 years*** *from the date of approval.*

Annual renewals will not be required. If the research extends beyond the expiration date, the Investigator must request a new exemption. Investigators should submit a final report to the IRB if the project is completed prior to the 5 year term.

Documents included in this review:

- ☒ Protocol
- ☐ Consent forms
- ☐ Assent forms
- ☐ Grant/contract
- ☐ Other:
- ☐ Recruiting tools
- ☐ Test instruments
- ☐ Attachment A: Radiation
- ☐ Letters of support
- ☐ External IRB approvals
- ☐ Translated documents
- ☐ Attachment B: Human materials
- ☒ Project revision(s)

Comments:

Principal Investigator responsibilities:

- Amendments to this study must be submitted to the IRB for review prior to initiating the change. Amendments may include, but are not limited to, changes in funding, personnel, target enrollment, study population, study instruments, consent documents, recruitment material, sites of research, etc.
- All study team members should be kept informed of the status of the research.
- Reports of unanticipated problems involving risks to participants or others must be submitted to the IRB within three calendar days.
- The Principal Investigator is required to securely store all study related documents on the OSU campus for a minimum of three years post study termination.

If you have any questions, please contact the IRB Office at IRB@oregonstate.edu or by phone at (541) 737-8008.

IRB Form v. 12/2010

APPENDIX A: IRB APPROVAL LETTER, IRB PROTOCOL, AND IRB APPLICATION

2) IRB Protocol

Protocol sections

1. Brief Description:

The main objective of this research is to investigate the impact of simulation games as a support tool for teaching and learning lean principles and methods. The impact will be measured using a variety of outcomes including student learning, student self-efficacy, and student attitudes. This investigation is aimed at understanding how to teach lean principles and methods effectively so that students can readily translate classroom knowledge to application in real-world organizations. The outcomes from this study will be used to complete a doctoral dissertation and may be used for future publications.

2. Background and Significance:

The benefit and basic principles of lean have been widely documented and applied across industries and more recently in service organizations. The implementation of lean principles resulted in more cost effective manufacturing. Because of the widespread application and benefits of lean principles, courses focusing on lean principles can be very valuable and extremely important to students' understanding of lean principles and methods, as well as to help prepare students to apply these concepts in the workplace.

Previous research has documented a variety of classroom activities such as collaborative learning, active learning, cooperative learning, hands-on exercises, role play, and simulation games that have been used and applied to groups of students of all ages. However, while lean principles have been taught for more than decade, stand-alone lean courses are rare, and the majority of students leave programs with a minimal understanding of lean principles.

Students need to get a sense of real-life situations before applying lean techniques and tools, which can be difficult to learn in a traditional classroom setting. Effective simulation games may help students understand lean concepts more quickly and remember them better than a traditional classroom setting.

Studying the impact of simulation games will help teaching faculty understand how to teach lean principles and methods effectively. The results of this study will provide insight into whether or not a nontraditional classroom setting (e.g. simulations games) will contribute to better student learning, improved student attitudes, and improved student self-efficacy.

3. Methods and Procedures:

3.1. Participant Selection

Participants will be divided into two groups, group one and group two. Group one includes student who are taking IE436/536 Lean Manufacturing System Engineering at Oregon State University during the fall term of 2010 and the fall term of 2011. Group two includes approximately 6 to 10 schools where students enrolls in a Lean Manufacturing Systems or related courses on lean principles and methods from other engineering and/or business universities or colleges.

3.2. Scheduling Surveys

For group one, this study will take place during the fall term of 2010 and the fall term of 2011 with undergraduate and graduate students who enroll IE436/536 Lean Manufacturing System Engineering at

Oregon State University. Participants will be asked to respond to eight surveys during class or labs in the Fall term of 2010 and Fall term of 2011. The surveys will be distributed on the following schedule:

Fall 2010

10/19/10 Survey1
10/27/10 Survey2 and Survey3
11/11/10 Survey4
11/24/10 Survey5 and Survey6
12/1/10 Survey7
12/2/10 Survey8

Fall 2011

10/18/11 Survey1
10/27/11 Survey2 and Survey3
11/11/11 Survey4
11/24/11 Survey5 and Survey6
11/29/11 Survey7
12/1/11 Survey8

For group two, a recruitment letter and/or recruitment email will be sent to instructors who will teach a lean manufacturing systems or related courses on lean principles and methods from other engineering and/or business universities or colleges. Two alternative methods for administering the survey will be used. A web page link and or hard copy surveys will be two alternative methods for survey administration provided. The hardcopy surveys along with a self-addressed return envelope and cover letter will be sent via mail to the instructor(s) after they are agreed to participate. The Web page link for this study which includes the cover letter and survey questions (survey 9 and survey 10) will be sent along with the recruitment email.

The cover letter will be the waiver of documentation of informed consent. The cover letter is on the first page of the Web page which provides information about the study, the purpose of the study, participants' rights, confidentiality information, instructions for completing the survey, contact information for both the principal investigator and student researcher, and IRB. This information will help participate in this study, participants will be asked to provide their school name and level of study (undergraduate and graduate). The survey will take approximately 10-15 minutes. Participants may choose to complete the survey then or return to the Web page to complete the survey at another time.

3.3. Survey Questions

The surveys used for this study are included in Appendix A-1, A-2, A-3, A-4, A-5, A-6, A-7, A-8, A-9, and A-10.

Participants in group one will be asked to respond to eight surveys during class or lab activities, while only two surveys (survey9 and survey10) will be given to each participant in group two.

3.4. Analysis plan

A spreadsheet (e.g. excel) will be used to summarize collected frequency distribution and measures of central tendency including Median, Mode, Mean, and Standard Deviation. Various statistical tools will be used to analyze the collected data.

4. Risks/Benefit Assessment:

4.1 Risks

We do not believe there are any discernible risks to those individuals who participate in the study.

4.2 Benefit Assessment

Participants would not directly benefit from this study. The outcomes from this study will be used to complete a doctoral dissertation and may be used for future publication. However, we hope that, in the future, other students and instructors might benefit from the study results.

4.3 Conclusion

We do not believe there are any discernible risks or benefits to the participants in this research.

5. Participant Population:

The approximate number of participants to be recruited over the life of the study is about 250 students. The study is not restricted to specific populations, gender or ethic group.

All participants included in this study will be divided into two groups, group one and group two. Group one includes both undergraduate and/or graduate students who enroll in IE436/IE536 (Lean Manufacturing System Engineering) at Oregon State University during the fall of 2010 and the fall of 2011. Group two includes approximately 6 to 10 schools where students enroll in a Lean Manufacturing System or related courses on lean principles and methods from other engineering and/or business universities or colleges.

6. Subject Identification and Recruitment:

For group one, all participants included in this study will be undergraduate and/or graduate students who enroll in IE436/IE536 (Lean Manufacturing System Engineering) at Oregon State University during the fall of 2010 and the fall of 2011. All participants are students in Dr. Toni L. Doolen's class. The study is not restricted to specific, gender or ethic group.

All participants who enroll in IE436/IE536 will be invited to participate in the study. All participants in IE436/IE536 are selected and invited to participant in the research study because they have direct experience in learning lean principles and methods with both in-class activities and lab simulation activities. Hence, the research study will analyze the impact of simulation games as a tool for learning and teaching lean principles and methods in the higher education classroom. Their feedback will be used to help us understanding the potential impact of simulation games as a tool in learning and teaching learn principles and methods in higher education classroom.

Student researcher will enter the class on October 19, 2010 and October 18, 2011 for the purpose of recruiting participants. The researchers will give a brief overview of the research study in front of the class; Participants will be provided with an Information sheet about the study. Please see attached files. Participants may ask any questions about the study, the possible risks and benefits, their rights as a volunteer, and anything else that is not clear at this time.

Participants will be given a survey (please see attached files) including questions focusing on student learning outcome achievement, student self-efficacy, and student attitudes. Participants will be asked to respond to eight surveys during class or labs in Fall 2010. The surveys will be distributed on the following schedule:

10/19/10 Survey1
10/27/10 Survey2 and Survey3
11/11/10 Survey4
11/24/10 Survey5 and Survey6
12/1/10 Survey7
12/2/10 Survey8

The following schedule shows survey distribution during the fall of 2011

10/18/11 Survey1
10/27/11 Survey2 and Survey3
11/11/11 Survey4
11/24/11 Survey5 and Survey6
11/29/11 Survey7
12/1/11 Survey8

Participants will be told to write the last four digits of their student ID on each survey. This information will be used to match their survey results from the beginning and end of the research study. Participants will be told that they will not lose any benefits or rights they would normally have if they choose not to volunteer. They can stop at any time during the study and still keep the benefits and rights they had before volunteering.

For group two, all participants will be undergraduate and/or graduate students who enrolled in a Lean Manufacturing System or related courses on lean principles and methods from other engineering and/or business universities or colleges. The study is not restricted to specific, gender or ethic group. Participants are selected and invited to participant in the research study because they have direct experience in learning lean principles and methods with lecture sessions, in-class activities, and/or lab simulation activities.

7. Compensation:
There is no compensation for any individual participating in the study.

8. Informed Consent Process:
For participants in group one, informed consent will give students the information needed to help them decide whether to be in the study or not. Participants may ask any questions about the study, the possible risks and benefits, their rights as a volunteer, and anything else that is not clear. Only researchers will have access to the collected

data. Participants can stop at any time during the study and still keep the benefits and rights they had before volunteering. They will not be treated differently if they decide to stop taking part in the study.

Student Recruitment Outline and Consent Discussion

1. Explain the purpose, procedures, risks, and alternative to participation of the research study verbally (please see attached file of verbal statement).
2. Distribute a written consent form (please see attached file of the information about student survey) to students. This process will help students decide whether to participate in the research study. This step will take approximately 5-10 minutes.
3. Answer any additional questions that students may have.
4. Distribute a survey (survey1) to a student who decides to take part in the study.

For participants in group two, a recruitment letter and/or recruitment email will be sent to instructors who will teach a lean manufacturing systems or related courses on lean principles and methods from other engineering and/or business universities or colleges. Two alternative methods for administering the survey will be used. A web page link and the hard copy surveys will be two alternative methods for survey administration provided. The hardcopy surveys along with a self-addressed after they are agreed to participate. Students will respond to the survey two times, after a collaborative learning session and after a lab simulation session, or after a lecture and after an in-class activity session. The hardcopy surveys will take approximately 10-15 minutes.

The Web page link for this study which includes the cover letter and survey questions (survey9 and survey10) will be sent along with the recruitment email. This information will help participants decide whether they wish to participant in the research study. If they agree to participate in this study, participants will be asked to provide their school name and level of study (undergraduate and graduate). The survey will take approximately 10-15 minutes. Participants may choose to complete the survey once or return to the Web page to complete the survey at another time.

Only researchers will have access to the collected data. Participants can stop at any time during the study and still keep the benefits and rights they had before volunteering. They will not be treated differently if they decide to stop taking part in the study.

9. Anonymity or Confidentiality:
A statement in the cover letter, "your responses will be protected to the extent permitted by law" will be included. Only researchers will have access to their information. Individual participant partial ID numbers will be used in the study, but this information will not be shown or shared in any public location. The outcome from

the study will be used to complete a doctoral dissertation and may be used for future publication without participant identification information. Student related documents will be securely stored by the P.I. for three years post study termination. Students who choose not to participate will not be deprived of any benefits.

10. Attachments:
Appendix A-1, A-2, A-3, A-4, A-5, A-6, A-7, A-8, A-9, A-10, Verbal Statement, Verbal Statement for photo, Cover letter for group one, Cover letter for group two, and Email recruitment.

APPENDIX A: IRB APPROVAL LETTER, IRB PROTOCOL, AND IRB APPLICATION

3) IRB application

OSU Oregon State UNIVERSITY

Institutional Review Board • Office of Research Integrity
B308 Kerr Administration Building, Corvallis, Oregon 97331-2140
Tel 541-737-8008 | Fax 541-737-3093 | IRB@oregonstate.edu
http://oregonstate.edu/research/ori/humansubjects.htm

INITIAL APPLICATION

Study ID

Study Title:	The impact of simulation games in higher education classroom.		
Principal Investigator:	Toni L. Doolen		
email address:	doolen@engr.orst.edu	Telephone:	75641
College, Center, or Institute:	Engineering		
If "other", indicate college:			
Department:	Other		
If "other", indicate department:	School of Mechanical, Industrial, and Manufacturing Engineering		

Please email the completed application and all relevant attachments to IRB@oregonstate.edu

- File names for all attachments should include the last name of the Principal Investigator, document title, and version date. For example: Smith_Protocol_10272009.doc
- All attachments should include the last name of the Principal Investigator, document title, version date, and page number.
- Signature page must be mailed, faxed, or scanned and emailed to the IRB.

1. **In one paragraph, state your primary research question or purpose:** This investigation is aimed to enhance an understanding the impact of simulation games as a support tool for teaching and learning lean principles and methods on student self-efficacy, student learning and student attitude. The research will be valuable to both organization and teaching faculty and will identify how to make learning effectiveness.

2. **Anticipated Level of Review**
   See Review Level Determination form at http://oregonstate.edu/research/ori/forms/IRBreview.doc

   ☒ Exempt ☐ Expedited ☐ Full Board

3. **Sources of Support for this project (pending or awarded)**

   ☐ Internal Funding Source: ______
   ☐ External Funding Source: ______
   Grant/contract number: ______
   Name of PI on Grant: ______
   Grant title: ______
   ☐ External source(s) of material, equipment, drugs, supplements, or devices: ______
   ☒ None of the above

   If funded, submit a copy of the grant or contract.

4. **Ethics and Compliance Training**

APPENDIX B: SIMULATION SCHEDULE FOR IE436/IE536

ENGR 436/536 Fall 2011 Lab Data Collection and Presentation Schedule (9/16/2011)

Week	Activity	Notes
1	Round 1 (2 runs)	Form into 8 teams/lab of 3 students
		(one team of 4, if needed), Assign team numbers
2	Round 1 (3 runs)	Summarize all metrics for runs 1, 2, 3, 4, 5
3	Round 1 Presentations	Teams 1a, 2a, 1b, 2b. 1c, 2c
4	Round 2 (4 runs)	
5	Round 2 Presentations	Teams 3a, 4a, 3b, 4b, 3c, 4c
6	Round 3 (4 runs)	
7	Round 3 Presentations	Teams 5a, 6a, 5b, 6b, 5c, 6c
8	Round 4(4 runs)	
9	NO LABS	
10	Round 4 Presentations	Teams 7a, 8a, 7b, 8b, 7c, 8c

APPENDIX C: A DETAILED SCHEDULE OF SURVEY ADMINISTRATION DATES

Year 2010

Participant Group One

10/19/10	Survey1
10/27/10	Survey2 and Survey3
11/11/10	Survey 4
11/24/10	Survey 5 and Survey 6
12/1/10	Survey 7
12/2/10	Survey 8

Year 2011

Participant Group One

10/04/10	Survey1
10/18/11	Survey2 and Survey3
11/3/11	Survey 4
11/10/10	Survey 5 and Survey 6
11/29/10	Survey 7
11/30/11	Survey 8

Year 2011

Participant Group Two

Two surveys were distributed in different times based on the university class schedule

APPENDIX D-1: STUDENT CONTENT KNOWLEDGE TEST (Jidoka1)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I.

Please provide the following information.

Class Level (please circle one): Undergraduate Graduate

Did you read your text books and/or class note before this class? (Please circle one):

Yes No

- If the answer is yes, approximately what percent of the assigned reading did you complete before coming to class? (Please circle one):

25% 50% 75% 100%

PART II

INSTRUCTIONS: Choose the best answer from those given for the following 10 questions.

1.	___________ means to stop the line automatically when something is wrong and then fix problems on the line. b. Poka-Yoke. c. Andon. d. Muda. e. Jidoka.
2.	Mistake proofing is also called ___________? a. Poka-Yoke. b. Andon. c. Muda. d. Jidoka.

	Use the following information to answer questions 3-5: ABC Company Ltd has been making superior rubber sealing products for over 20 years. They have a plant in California and just constructed a new facility in Mexico. They are well-known manufacturers and exporters of durable products. However, the plant has several problems. The largest problems are achieving on-time delivery goals and high scrap rates due to poor processing.
3.	As John, a plant manager of the ABC company Ltd, walked through the plant, he found that employees walk halfway across the production floor to carry materials to and from containers. What type of waste was found by John? a. Motion. b. Overprocessing. c. Overproduction. d. Transportation.
4.	John eliminates a visual inspection at the end of the manufacturing line. Which of the following techniques will enable John to identify defects and correct the defects earlier in the process? a. Poka-Yoke. b. Jidoka. c. Andon borad. d. All of the above.
5.	John uses ________________ as a system to signal for help when a defect is found. a. Poka-Yoke. b. Andon board. c. Jidoka. d. Kanban.
6.	Which of the following is true about Poka-Yoke? a. Poka-Yoke is only use for self-check inspection and source inspection. b. Poka-Yoke is used to replace any quality system that companies are used. c. Poka-Yoke is used either shut down the process or signals the operator to stop the process when an error occurs. d. Poka-Yoke is simple and cheap but provide slow feedback to the operator.
7.	If a mistake has already occurred, but has not yet resulted in a defect, this refers to which one of the following types of Poke-Yoka? a. Administrate Poka-Yoke. b. Warning Poka-Yoke. c. Control Poka-Yoke. d. None of the above.

8.	If a plant manager requires that each operation inspects the work of the previous operationWhich of the following may occur? a. Discovers defects. b. Reduces defects. c. Eliminates defects. d. All of the above.
9.	Under a Poka-Yoke system to improve quality, which of the following problem resolving approaches can we utilize? a.Improving work procedures. b.Preventive maintenance. c.Constant monitoring of equipment. d.All of the above.
10.	At the end of submitting a purchase order, a customer will be worried if the provided zip code does not match the customer's address. This is an example of which of the following techniques? a. Poka-Yoke. b. Jidoka. c. Andon. d. Muda.

APPENDIX D-2: STUDENT CONTENT KNOWLEDGE TEST (Jidoka2)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I.

Please provide the following information.

Class Level (please circle one): Undergraduate Graduate

Did you read your text books and/or class note before this class? (Please circle one):

Yes No

- If the answer is yes, approximately what percent of the assigned reading did you complete before coming to class? (Please circle one):

25% 50% 75% 100%

PART II

INSTRUCTIONS: Choose the best answer from those given for the following 10 questions.

1.	A plant manager requires that machines automatically stop the process when something is wrong. This is an example of ___________. a.Poka-Yoke. b.Andon. c.Jidoka. d.Muda.
2.	Which the following is a benefit of Poka-Yoke? a.Reduce number of errors. b.Reduce over processing. c.Reduce inventory level. d.All of the above.
3.	Which one of the following is NOT true about Poka-Yoke? a. Poka-Yoke devices are used to detect errors before they become defects. b. Poka-Yoke devices can be used at any step of a manufacturing process to eliminate human error. c. Poka-Yoke devices are only used to detect abnormal situations before they occur in a production process. d. None of the above.

4.	Recently ABC company failed to meet the target cycle time because of a bottleneck at the rework process. The company requires __________ to minimize errors leading to rework and reduce the level of inventory at the rework process. a. Poka-Yoke. b. Andon. c. Jidoka. d. Muda.
5.	The ABC Company has many machines, and there are very few workers to operate the machines. __________ would be very useful to visually signal which machines are down. a.Poka-Yoke. b.Andon board. c.Jidoka. d.Muda.
6.	Linda always checks work from the previous operation at her station before she starts her own work. What type of inspection is this? a.Self-inspection. b.Source inspection. c.Successive inspection. d.None of the above.
7.	Which one of the following is NOT an example of Poka-Yoke? a.Circuit breakers. b.A coin return machine at grocery store. c.A fence around a house. d.Battery charge warning light.
8.	Which of the following is an example of Andon? a. A line supervisor uses color coding to allow workers to pick up the correct materials. b.Car manufactures build an oil pressure warning light on car dashboard to let drivers know the tank is getting close to empty. c.Manufacturers build the three-prong electrical plug which allows only one way to plug it into the wall socket. d.All of the above.
9.	You will hear a continuous beeping sound at an ATM machine when a bankcard is ejected after a transaction. What type of Poka-Yoke is this? a. Administration Poka-Yoke. b.Warning Poka-Yoke. c.Control Poka-Yoke. d.Setting Poka-Yoke.

10.	A poor layout can result in the excessive movement and handling of parts. This is an example of what type of waste? a. Motion. b. Transportation. c. Overprocessing. d. Overproduction.

PART III

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

	Question	Scale Level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	As a result of in-class activities, I believe that I will be able to respond to exam questions on Jidoka.	1	2	3	4	5
2	The in-class activities increased my confidence in my own understanding of Jidoka concepts.	1	2	3	4	5
3	I am certain I understand the most difficult concepts used in the in-class activities today.	1	2	3	4	5
4	As a result of today's in-class activities, I have no doubts about my capability to do well on assignments asking about Jidoka.	1	2	3	4	5
5	As a result of today's in-class activities, I can now explain to my friends what I have learned about Jidoka.	1	2	3	4	5
6	I am certain I can master the skills being taught in the in-class activities today.	1	2	3	4	5

APPENDIX D-3: STUDENT CONTENT KNOWLEDGE TEST (Jidoka3)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I

INSTRUCTIONS: Choose the best answer from those given for the following 10 questions.

1.	Which one of the following lean tools is used to prevent worker and machine error? a.Jidoka. b.Poka-Yoke. c.Andon. d.Muda.
2.	A photoelectric sensor is used to count the number of parts required to complete the operation. The photoelectric sensor is an example of ___________. a.Kaizen. b.Poka-Yoke. c.Value Stream Mapping. d.Muda.
3.	A plant manger needs to decrease the defect rate in order to meet the company's profit objectives. The plant manager requires that all plant workers assess the quality of their own work by checking every unit produced. Which one of the following inspection methods is being used? a. Self-check inspection. b. Source inspection. c. Successive inspection. d. Judgment inspection.
4.	What strategies should the plant implement to be successful in this question 3 inspection method? a. Use more inspectors. b. Train workers. c. Develop team. d. All of the above.
5.	Which of the following lean techniques can be used to immediately detect scrap? a. Poka-Yoke. b. Jidoka. c.Andon board. d.All of the above.

6.	A plant manager installed boards with light bulbs and put them above each machine to show whether equipment was running. This is an example of: a. Poka-Yoke. b. Andon. c. Jidoka. d. Muda.
7.	A sensor alarm at the Valley Library gate is an example of which one of the following types of Poka-Yoke? a.Administration Poka-Yoke. b.Warning Poka-Yoke. c.Control Poka-Yoke. d.Setting Poka-Yoke.
8.	ABC manufacturing requires a fixed number of operations within a process. Which one of the following lean tools can be used to improve the ABC manufacturing? a.Poka-Yoke. b.Andon board. c.Jidoka. d.Kaizen
9.	Which of the following is used to prevent the error of placing an extra part in a kit when a product has a fixed number of parts required? a.Poka-Yoke. b.Andon. c.Jidoka. d.Muda.
10.	In the service industry, a customer is passed from person to person during a phone inquiry without gaining information. This is an example of what type of waste? a.Motion. b.Transportation. c.Overprocessing. d.Overproduction.

PART II

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

	Question	Scale Level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	As a result of lab activities, I believe that I will be able to respond to exam questions on Jidoka.	1	2	3	4	5
2	The lab activities increased my confidence in my own understanding of Jidoka concepts.	1	2	3	4	5
3	I am certain I understand the most difficult concepts used in the lab activities today.	1	2	3	4	5
4	As a result of today's lab activities, I have no doubts about my capability to do well on assignments asking about Jidoka..	1	2	3	4	5
5	As a result of today's lab activities, I can now explain to my friends what I have learned about Jidoka.	1	2	3	4	5
6	I am certain I can master the skills being taught in the in-class activities today.	1	2	3	4	5

APPENDIX D-4: STUDENT CONTENT KNOWLEDGE TEST (pull1)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I.

Please provide the following information.

Class Level (please circle one): Undergraduate Graduate

Did you read your text books and/or class note before this class? (Please circle one):

Yes No

- If the answer is yes, approximately what percent of the assigned reading did you complete before coming to class? (Please circle one):

25% 50% 75% 100%

PART II

INSTRUCTIONS: Choose the best answer from those given for the following 10 questions.

1.	What does the word "Kanban" mean? a.Continuous improvement. b.Card. c.Low inventory. d.Mistake proof.
2.	Which of the following is true about a pull production system? a.Pull production is also called a just-in-time production. b.There is little difference between "push" or "pull" production systems. c.In the pull production system, ordering decisions are based on inventory and forecasts. d.None of the above.
3.	Which one of the following is an example of a push system? a.Snack vending machines. b.Supermarket shelves. c.Laptop customization at Dell. d.None of the above.

4.	___________ provides fast response to changes in production demand. a.A pull production system. b.A push production system. c.All of the above. d.None of the above.
5.	Kanban are used to __________. a.Control materials used in a system. b.Notify operators when material is needed before a stock out occurs,. c.Ensure sufficient inventory to buffer from disruptions caused by machine breakdowns, defects, and other unplanned shop floor realities. e.All of the above.
6.	A Kanban that is used in factory floors to move or withdraw inventory is called ___________. a. A production Kanban. b. A conveyance Kanban. c. A delivery Kanban. d. None of the above.
7.	What is a benefit of reducing inventory in a pull production system? a.Reducing order costs. b.Reducing risk of production shortages. c.Reducing obsolete inventory levels. d.All of the above.
8.	XYZ Company uses an average of 2000 bottles of wine per year. The company finds that they should order 200 bottles of wine whenever the inventory level drops to 20 bottles of wine. Which one of the following statement is true? a. 20 units is the safety stock. b. 20 units is the order quantity. c. 2000 units is the reorder point. d. 200 units is the safety stock.
9.	After looking at the XYZ Company process, a kaizen team found that raw materials in the storage room do not have labels and are not well-organized. As a result, operators require additional time to locate the material. What type of waste will result from this situation? a.Over processing. b.Transportation. c.Motion. d.Waiting.

10.	Which one of the following statement is NOT true about Kanban? a.In Kanban systems, operators send defects to downstream process. b.In Kanban systems, operators at downstream processes withdraw only what they need from upstream process. c.In Kanban systems, cards are used to signal and communicate reorder information. d.None of the above.

APPENDIX D-5: STUDENT CONTENT KNOWLEDGE TEST (pull2)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I.

Please provide the following information.

Class Level (please circle one): Undergraduate Graduate

Did you read your text books and/or class note before this class? (Please circle one):

Yes No

- If the answer is yes, approximately what percent of the assigned reading did you complete before coming to class? (Please circle one):

25% 50% 75% 100

PART II

INSTRUCTIONS: Choose the best answer from those given for the following 10 questions.

1.	___________ is one of the most common tools used in stockless production. a.Kaizen b.Kanban c.Poka-Yoke d.SMED
2.	Which of the following are necessary conditions for a pull production system? a.Setup times must be small. b.Plant layout must facilitate linking. c.Planning and control responsibilities must reside in frontline supervisors and workers. d.All of the above.
3.	___________ is well suited to small lot production. a.A pull production system b.A push production system c.All of the above. d.None of the above.

4.	Which of the following is an example of a push production system? a. Dell allows customers to build their own computer specifications on the internet. b. A workers at 7-eleven will refill merchandise on the display shelves based only on what the customer takes from the shelves. c. A pre-cooked fast food company prepares food based on sales forecasts. d. None of the above.
5.	Which of the following is true? a. In Kanban systems, material containers have either a withdrawal or production Kanban. b. The number of Kanban cards should be increased overtime. c. A Kanban can only be used to set the order quality. d. An empty container can be exchanged for a full container at the storage location without Kanban card attached.
6.	___________ is used to release an order to the preceding station to build the lot size indicated on the card. a. A conveyance Kanban b. A production Kanban c. A delivery Kanban d. None of the above.
7.	Which one of the following is NOT a reason to hold inventory? a. To meet unexpected customer demand. b. To respond to delays in incoming goods. c. To reduce order costs. d. All of the above are reasons to hold inventory.
8.	Each time when the inventory of product X drops to 10 units, 200 units of product X will be ordered. Which one of the following statements is true? a.10 units is the safety stock. b.10 units is the order quantity. c.200 units is the reorder point. d.200 units is the safety stock.
9.	Which of the following is the purpose of implementing a pull production system? a.To prevent overproduction. b.To reduce inventory. c.To reduce waiting times. d.All of the above.

10.	Which of the following is true about the Kanban System? a. In Kanban systems, the size of Kanban containers is usually large to reduce setup costs. b. In Kanban systems, the number of Kanbans decreases as safety stock is increased. c. In Kanban systems, a customer workstation signals a supplier workstation when production is needed. e. All of the above.

PART III

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

	Question	**Scale Level**				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	As a result of in-class activities, I believe that I will be able to respond to exam questions on a pull production system.	1	2	3	4	5
2	As a result of in-class activities, I believe that I can describe the difference between a pull and a push production system.	1	2	3	4	5
3	The in-class activities increased my confidence in my own understanding of concepts of pull production systems.	1	2	3	4	5
4	I am certain I understand the most difficult concepts used in the in-class activities today.	1	2	3	4	5
5	As a result of in-class activities, I can now explain to my friends what I have learned about a pull production system.	1	2	3	4	5
6	I am certain I can master the skills being taught in the in-class activities today.	1	2	3	4	5

APPENDIX D-6: STUDENT CONTENT KNOWLEDGE TEST (pull3)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I

INSTRUCTIONS: Choose the best answer from those given for the following 10 questions.

1.	___________ is a signal. a.Kanban b.Poka-Yoke c.Kaizen d.Jidoka
2.	Which of the following is true? a.In pull systems, Poka-Yoke is used as a visual system for controlling production. b.In pull systems, resources are provided to the customer based on schedules. c.In pull systems, a manufacturer will produce as much as possible, just in case the machine goes down. d.In pull systems, inventory is controlled by visual management.
3.	Which of the following is type of signal used in pull production systems? a. Cards. b. Containers. c. Andon board. d. All of the above.
4.	Which of the following is an example of a pull production system? a.Grandma Bakery bakes cookies based on sales forecasts. b.A plant manager keeps a lot of materials in stock to reduce order costs. c.A furniture manufacturer produces 1,000 dining tables each day to maximize the utilization of the capacity of the machine and minimize the impact of setup times. d.None of the above.
5.	Which of the following is **NOT** true about Kanban? a.In Kanban systems, a breakdown in the Kanban system can result in the entire production line shutting down. b.Kanban systems are suitable for products with short production runs and highly variable product demand. (X) d.In pull systems, Kanban is used as a visual system for controlling production. e.None of the above.

6.	___________ is used to signal when a machine has broken down. a.A conveyance Kanban b.A production Kanban c.A delivery Kanban d.None of the above
7.	Which of the following is **NOT** a type of inventory? a. Raw materials. b. Work-in-progress. c. Spare parts for equipment. d. All of the above are types of inventory.
8.	The James Toy Company has had problems with high inventory levels of plastic wheels that are used to make several toys. To solve the problem, a plant manager plans a new inventory decision rule as followings "if the boxes of plastic wheels drops to 10 boxes, then the company will place an order for an additional 100 boxes of plastic wheels". Which one of the following statements is true? a. Ten boxes of plastic wheels are the safety stock. b. Ten boxes of plastic wheels are the order quantity. c. One hundred boxes of plastic wheels are the safety stock. d. One hundred boxes of plastic wheels are reorder point.
9.	An order clerk at the XYZ company creates multiple forms with the same customer information when the customer placed the order. This is an example of what type of waste? a. Over processing. b. Overproduction. c. Motion. d. Transportation.
10.	Which of the following are true? a. Kanban systems are suitable for products with short production runs and highly variable production demand. b. In Kanban systems, the size of Kanban containers is usually large to reduce setup cost. c. The number of Kanban cards should be decreased over time in order to better link processes and to eliminate waste. d. All of the above.

PART II

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

	Question	Scale Level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	As a result of lab activities, I believe that I will be able to respond to exam questions on a pull production system.	1	2	3	4	5
2	The lab activities increased my confidence in my own understanding of concepts of a pull production system.	1	2	3	4	5
3	I am certain I understand the most difficult concepts used in the lab activities today.	1	2	3	4	5
4	As a result of today's lab activities, I have no doubts about my capability to do well on pull production system assignments.	1	2	3	4	5
5	As a result of today's lab activities, I can now explain to my friends what I have learned about pull production system.	1	2	3	4	5
6	I am certain I can master the skills being taught in the lab activities today.	1	2	3	4	5

APPENDIX D-7: STUDENT ATTITUDE SURVEY (Attitude-Collaborative)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

	Question	**Scale Level**				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	I prefer in-class activities that are challenging so I can learn new things.	1	2	3	4	5
2	I prefer in-class activities that arouse my curiosity, even if they are difficult.	1	2	3	4	5
3	I prefer in-class activities that I will learn something from even if they require more work.	1	2	3	4	5
4	I prefer in-class activities that I can learn something from even if they do not guarantee a good grade.	1	2	3	4	5
5	Learning from in-class activities helps prepare me for tests.	1	2	3	4	5
6	Learning from in-class activities helps me get good grades on tests.	1	2	3	4	5
7	I participate in in-class activities because I am supposed to.	1	2	3	4	5
8	I prefer in-class activities because I am sure I can do them.	1	2	3	4	5
9	As a result of in-class activities, I believe that I will able to use what I have learned in other courses.	1	2	3	4	5

	Question	Scale Level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
10	It is important for me to learn what is taught in in-class activities.	1	2	3	4	5
11	I think that what I have learned from in-class activities is useful for me to know.	1	2	3	4	5
12	As a result of in-class activities, I believe that I can apply what I have learned to real-world problems.	1	2	3	4	5
13	I enjoy participating in in-class activities.	1	2	3	4	5
14	I feel that time flies when I participate in in-class activities.	1	2	3	4	5
15	After finishing in-class activities, I look forward to the next class.	1	2	3	4	5
16	I would like to spend more time on in-class activities.	1	2	3	4	5

Other comments or suggestions on in-class activities:

____

____

____

____

APPENDIX D-8: STUDENT ATTITUDE SURVEY (Attitude-Simulation)

INSTRUCTIONS: Please include the last four digits of your student ID at the top of the first page of the survey. This information will be used to match your survey results from the beginning and end of the research study. The test will take approximately 10-15 minutes to complete.

PART I

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

	Question	Scale Level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1	I prefer lab activities that are challenging so I can learn new things.	1	2	3	4	5
2	I prefer lab activities that arouse my curiosity, even if they are difficult.	1	2	3	4	5
3	I prefer lab activities that I will learn something from even if they require more work.	1	2	3	4	5
4	I prefer lab activities that I can learn something from even if they do not guarantee a good grade.	1	2	3	4	5
5	Learning from lab activities helps prepare me for tests.	1	2	3	4	5
6	Learning from lab activities helps me get good grades on tests.	1	2	3	4	5
7	I participate in lab activities because I am supposed to.	1	2	3	4	5
8	I prefer lab activities because I am sure I can do them.	1	2	3	4	5
9	As a result of lab activities, I believe that I will able to use what I have learned in other courses.	1	2	3	4	5
10	It is important for me to learn what is taught in lab activities.	1	2	3	4	5
11	I think that what I have learned from lab activities is useful.	1	2	3	4	5
12	As a result of lab activities, I believe that I can apply what I have learned to real-world problems.	1	2	3	4	5

	Question	Scale Level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
13	I enjoy participating in lab activities.	1	2	3	4	5
14	I feel that time flies when I participate in lab activities.	1	2	3	4	5
15	After finishing lab activities, I look forward to the next lab.	1	2	3	4	5
16	I would like to spend more time on lab activities.	1	2	3	4	5

APPENDIX E-1: SURVEY EVALUATION FOR STUDENT SELF-EFFICACY AND ATTITUDES

SURVEY EVALUATION SURVEYS:

PART I

Note: The questions below were developed to measure **self-efficacy** for learning and performance. Self-efficacy refers to belief that one has the capability to learn or perform a task or to apply what one has learned.

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

Survey Items to Evaluate		Scale level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1) As a result of lab activities, I believe that I will be able to respond to exam questions on lean manufacturing.	1. This item is a good measure of student self-efficacy.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
2) The lab activities increased my confidence in my own understanding of lean manufacturing concepts.	1. This item is a good measure of student self-efficacy.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5

Survey Items to Evaluate		Scale level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
	4. Other comments or suggestions on this item.					
3). I am certain I understand the most difficult concepts used in the lab activities today.	1. This item is a good measure of student self-efficacy.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
4). As a result of today's lab activities, I have no doubts about my capability to do well on lean manufacturing assignments.	1. This item is a good measure of student self-efficacy.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this question.					
5). As a result of today's lab activities, I can now explain to my friends what I have learned about lean manufacturing.	1. This item is a good measure of student self-efficacy.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5

Survey Items to Evaluate		Scale level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
6). I am certain I can master the skills being taught in today's lab activities.	1. This item is a good measure of student self-efficacy.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

PART II

Note: The questions below were developed to measure of **intrinsic goal orientation**. Intrinsic goal orientation refers to the degree to which one perceives his/herself to be participating in a task because the task itself is perceived as challenging and arouses curiosity.

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

Items in questions	**Survey evaluation**	**Scale level**				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1). I prefer lab activities that are challenging so I can learn new things.	1. This item is a good measure of student intrinsic value.	1	2	3	4	5
	2. The question is clear.	1	2	3	4	5
	3. The question is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this question.					
2). I prefer lab activities that arouse my curiosity, even if they are difficult.	1. This item is a good measure of student intrinsic value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
3). I prefer lab activities that I will learn something from even if they require more work.	1. This item is a good measure of student intrinsic value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
4). I prefer lab activities that I can learn something from even if they do not guarantee a good grade.	1. This item is a good measure of student intrinsic value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

PART III

Note: The questions below were developed to measure of **extrinsic goal orientation**. Extrinsic goal orientation refers to degree to which one perceives his/herself to be participating in a task because the task itself is connected with a desired external motivation, e.g., a high course grade, a reward, or a course credit.

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1). Learning from lab activities helps prepare me for tests.	1. This item is a good measure of student extrinsic value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
2). Learning from lab activities helps me get good grades on tests.	1. This item is a good measure of student extrinsic value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
3). I participate in lab activities because I am supposed to.	1. This item is a good measure of student extrinsic value.	1	2	3	4	5

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
4). I prefer lab activities because I think I can do them.	1. This item is a good measure of student extrinsic value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

PART IV

Note: The questions below were developed to measure of **task value**. Task value refers to degree to which one perceives his/herself to be participating in a task because the task itself is perceived as important to him/her.

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1). As a result of lab activities, I believe that I will able to use what I have learned in other courses.	1. This item is a good measure of student task value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
2). It is important for me to learn what is taught in lab activities.	1. This item is a good measure of student task value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
3). I think that what I have learned from lab activities is useful.	1. This item is a good measure of student task value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
4). As a result of lab activities, I believe that I can apply what I have learned to real-world problems.	1. This item is a good measure of student task value.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

PART V

Note: The questions below were developed to measure of **enjoyment**. Enjoyment refers to degree to which one perceives his/herself to be participating in a task because the task itself is fun and/or enjoyable.

INSTRUCTIONS: Please indicate your level of agreement with each of the following statements by circling the appropriate response on a scale of 1 to 5.

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
1). I enjoy participating in lab activities.	1. This item is a good measure of student enjoyment.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
2). I feel that time flies when I participate in lab activities.	1. This item is a good measure of student enjoyment.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

Items in questions	Survey evaluation	Scale level				
		Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**
3). After finishing lab activities, I look forward to the next lab.	1. This item is a good measure of student enjoyment.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					
4). I would like to spend more time on lab activities.	1. This item is a good measure of student enjoyment.	1	2	3	4	5
	2. The item is clear.	1	2	3	4	5
	3. The item is easy to understand.	1	2	3	4	5
	4. Other comments or suggestions on this item.					

Other comments or suggestions

APPENDIX E-2: SURVEY EVALUATION FOR STUDENT SELF-EFFICACY AND ATTITUDES

SURVEY EVALUATION RESULTS:

1) SELF-EFFICACY BELIEFS

Survey Items to Evaluate	Survey Evaluation	Content Validity Ratio
1) As a result of lab activities, I believe that I will be able to respond to exam questions on lean manufacturing.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	
2) The lab activities increased my confidence in my own understanding of lean manufacturing concepts.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
3). I am certain I understand the most difficult concepts used in the lab activities today.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	1
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	

Survey Items to Evaluate	Survey Evaluation	Content Validity Ratio
4). As a result of today's lab activities, I have no doubts about my capability to do well on lean manufacturing assignments.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	
5). As a result of today's lab activities, I can now explain to my friends what I have learned about lean manufacturing.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	1
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
6). I am certain I can master the skills being taught in today's lab activities.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	

2) INTRINSIC GOAL ORIENTATION

Items in questions	Survey evaluation	Content Validity Ratio
1). I prefer lab activities that are challenging so I can learn new things.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	1
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
2). I prefer lab activities that arouse my curiosity, even if they are difficult.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.2
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	
3). I prefer lab activities that I will learn something from even if they require more work.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	1
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
4). I prefer lab activities that I can learn something from even if they do not guarantee a good grade.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.6

Items in questions	Survey evaluation	Content Validity Ratio
	4.Other comments or suggestions on this item.	

3) EXTRINSIC GOAL ORIENTATION

Items in questions	Survey evaluation	Content Validity Ratio
1). Learning from lab activities helps prepare me for tests.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	0.6
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
2). Learning from lab activities helps me get good grades on tests.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	1
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
3). I participate in lab activities because I am supposed to.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.2
	4.Other comments or suggestions on this item.	

Items in questions	Survey evaluation	Content Validity Ratio
4). I prefer lab activities because I think I can do them.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	

4) TASK VALUE

Items in questions	Survey evaluation	Content Validity Ratio
1). As a result of lab activities, I believe that I will able to use what I have learned in other courses.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
2). It is important for me to learn what is taught in lab activities.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	
3). I think that what I have learned from lab	1.This item is a good measure of student	1

Items in questions	Survey evaluation	Content Validity Ratio
activities is useful.	self-efficacy.	
	2.The item is clear.	1
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
4). As a result of lab activities, I believe that I can apply what I have learned to real-world problems.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	0.6
	4.Other comments or suggestions on this item.	

5) ENJOYMENT

Items in questions	Survey evaluation	Content Validity Ratio
1). I enjoy participating in lab activities.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	0.6
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
2). I feel that time flies when I participate in lab activities.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	1

Items in questions	Survey evaluation	Content Validity Ratio
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
3). After finishing lab activities, I look forward to the next lab.	1.This item is a good measure of student self-efficacy.	1
	2.The item is clear.	1
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	
4). I would like to spend more time on lab activities.	1.This item is a good measure of student self-efficacy.	0.6
	2.The item is clear.	0.6
	3.The item is easy to understand.	1
	4.Other comments or suggestions on this item.	