SURVEY INSTRUMENT TO FACILITATE CONTINUOUS IMPROVEMENT OF LEAN TEACHING MATERIALS: A FIRST RUN STUDY

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ABSTRACT

Training workshops are a popular means to transfer knowledge of lean construction principles to industry stakeholders. Although numerous workshops are being offered by various members of the lean construction community, the amount of understanding that has been successfully transferred to participants during a workshop is not always measured or known, making it difficult to assess success.

The purpose of this research is to develop and test an assessment instrument to indicate the level of understanding that was transferred during a three-day lean construction workshop.

Drawing on published and unpublished case studies, we developed lean construction teaching materials for a three-day workshop and tested them on a healthcare facility owner and its most frequently engaged architects, engineers, general contractors and trade partners. To test the effectiveness of the teaching materials, we developed an anonymous, paired, pre-and post-workshop assessment survey instrument. Participants were asked to (a) rate their level of confidence in their understanding of lean construction principles, and (b) provide specific examples of potential application of the named principles.

Participants rated their confidence levels in understanding of specific lean principles higher after the workshop than before (all comparisons of means were statistically significant to $p<=0.05$). Also, participants described twice as many potential construction applications of lean principles after the workshop than before, implying an increased level of understanding which translated into actionable items. Results from this research suggest that the lean workshop format delivered was relatively effective in transferring basic knowledge and application of lean principles. However, there is also clear need to continually improve our workshop teaching materials.

KEYWORDS

Lean construction, teaching, learning, education

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INTRODUCTION

Becoming educated in lean thinking is critical to the development of a lean culture in the OAEC industry (Owner, Architect, Engineering, and Construction). Various lean seminars are offered at Lean Construction Institute branches (throughout the US; LCI 2012), as prefaces to IGLC conferences (IGLC 2012), as separate training workshops for academic educators (LCI Academic Forum 2012), and as formal standalone full-semester courses at universities such as the University of California, Berkeley, North Carolina State University, Michigan State University, and Texas A&M University. Numerous lean consultants can also be hired to provide individualized training to specific project teams, as is revealed by nearly 15 million hits when "lean consultant" is inputted into Google's search engine.

Some practitioners and academics have expressed concern that lean concepts may be difficult to grasp at first (personal communication, Chuck Greco 2009, Linbeck; personal communication 2010, Jorge Vanegas, Texas A&M). Others have communicated a desire for a more clear definition of lean principles, resulting in the development of an on-line lean construction course from the Associated General Contractors (AGC 2012). It is certainly true that, in order for lean principles to be successfully applied, the organizational culture must be openly amenable and supportive of their widespread application, because lean thinking prioritizes system-wide optimization over individualized optimization. Successful application of lean principles depends on the adoption of lean culture by most, if not all, project stakeholders. This requirement calls for the development of a high impact training program where short-term and long-term impact on participants can be measured.

To respond to this need, we developed a three-day cross disciplinary workshop, based on teaching materials from a number of sources, as described in the Methodology section of this paper, and tested the effectiveness of the workshop with a paired assessment survey instrument administered to participants immediately before and after the workshop.

This paper documents a three-day lean construction workshop as a first run study, and attempts to measure the success of knowledge transfer of: (1) understanding of specific lean principles, (2) application of the same lean principles. The participants were asked to respond to both a pre- and post-conference (workshop) survey about their confidence in understanding specific lean principles and suggestions about how they might apply them to their own organizations. This paper represents the first phase of a longer term longitudinal study that includes a six month follow-up with all parties.

METHODOLOGY

The owner's representative for a western US-based healthcare facility that serves a metropolitan population of nearly 650,000 residents contacted the first author of this paper after reading an article by the same (Hamilton and Rybkowski 2011). The 522-bed acute care facility offers full emergency, medical, and surgical services; for five years in a row the facility has been named as one of "America's 50 best hospitals."

Approximately two months before the start of the workshop, the owner's representative contacted his most frequently used professionals in architecture, engineering and construction. One month before the three-day workshop, participants were asked to purchase and read Jeffrey Liker's The Toyota Way (Liker 2004).

The three day workshop was held all day on a Thursday, Friday and Saturday in late April, from 8:30 am to 5:30 pm on Thursday, 9:15 am to 4:45 pm on Friday, and 8:30 am to 3:30 pm on Saturday. Because they were repeatedly invited to work on his projects, the owner required participants shown in Table 1 to attend the workshop. Although a handful of the invited participants could not attend all three days of the workshop, the majority of them did.

Table 1: Roles and titles of workshop participants and number of participants in role

Participant roles	**Number of participants in this role**	**Titles of workshop participants***
Owner	3	facilities director, director of biomed, construction manager
Architect	4	principal , project architect, interior designer,
General contractor	7	healthcare VP, VP, senior PM, assistant PM, estimator
MEP trade partner	8	owner , senior PM, PM, QA/QC officer
Mechanical engineer	1	senior mechanical engineer
Total in attendance	**23**	--

* VP = Vice president, PM = Project manager, QA/QC = Quality Assurance/Quality Control

Table 2: Day I Activity breakdown of three-day workshop on Lean Construction

	Activity	Duration (minutes)	Group size[1]
DAY I. Objective: Introduction to Lean Concepts			
•	Getting to know fellow participants and facilitators & testing for current state of lean knowledge		
1.0.1	Participants sign in + given name tags	30	plenary
1.0.2	Introduction of facilitators and participants	10	plenary
1.0.3	Participants take pre-conference confidence survey	30	plenary
•	Defining the current state of the industry		
1.1.1	Problems in construction (brainstorming session)	20	plenary
1.1.2	Deming's Red Bead Game	25	plenary
•	Lean Construction: How it is responding to the current state of the industry		
1.2.1	Definition of lean construction (step diagram)	5	plenary
•	Lean "soft" skills: Culture of Respect		
1.3.1	Maroon & White game	90	half groups
1.3.2	CII Alignment exercise	90	half groups
•	Lean "hard" skills: The Mechanics of Lean		
1.4.1	Dice game	45	half groups
1.4.2	5S game	45	half groups
1.4.3	Airplane game	90	half groups
•	Taking stock of Day 1: modeling continuous improvement		
1.5.1	Plus/Delta for Day I	30	plenary

A democratic tone for the workshop was established early on as residents were asked to "leave their hats at the door." The role of facilitators was to ensure that participants

felt comfortable communicating the truth, respectfully, and that a culture of respect prevailed at all times. Participants were given name tags with colored stickers designating specific cluster groups to which they were assigned. Cluster groups were determined in advance so that participants within each group represented a cross-section of disciplines and a range of functional hierarchy positions.

One assistant professor and three graduate students, who were previously trained in lean, including one PhD student, co-facilitated the workshop.

A breakdown of workshop activities over the three days is shown in Table 2. Activities were arranged so that participants would be systematically introduced to lean concepts during Days I and II (primarily via group games and exercises on Day I, and via chapter-by-chapter discussions of Liker's The Toyota Way (2004), on Day II), and the application of lean principles through presentation of concrete case studies on Day III.

Simulation games were designed to actively illustrate lean construction principles. Some—though not all—of the games were adopted from those developed by the Lean Construction Institute. The purpose of each simulation game and its respective (known) origin is listed in Table 3.

Table 2: Day II Activity breakdown of three-day workshop on Lean Construction

	Activity	Duration (minutes)	Group size[1]
DAY II: Objective: History and Theory of Lean			
• Getting to know fellow participants and facilitators			
2.0.1	Participants sign in + given name tags	15	plenary
• History of Lean			
2.1.1	Tracing Lean through 200 years	20	plenary
2.1.2	Video: "The Easier Way" (1946) <http://www.archive.org/details/EasierWa1946>	15	plenary
2.1.3	Video: "W. Edwards Deming" (Parts 1, 2, & 3) <http://www.youtube.com/watch?v=GHvnIm9UEoQ>	30	plenary
• Reading The Toyota Way			
2.2.1	Part One: Ch. 3 (The heart of the Toyota Production System: Eliminating waste)	45	cluster groups
2.2.2	Part Two: Section I: Ch. 7 (Long-term philosophy)	45	cluster groups
2.2.3	Part Two: Section II: Ch. 8-14 (The right process will produce the right results)	45	cluster groups
2.2.4	Part Two: Section III: Ch. 15-17 (Add value to the organization by developing people and partners)	45	cluster groups
2.2.5	Part Two: Section IV: Ch. 18-20 (Continuously solving root problems drives organizational learning)	45	cluster groups
2.2.6	Group sharing of cluster group reactions to The Toyota Way	30	plenary
• Taking stock of Day 2: modeling continuous improvement			
2.3.1	Plus/Delta for Day II	30	plenary

Table 2: Day III: Activity breakdown of three-day workshop on Lean Construction

	Activity	Duration (minutes)	Group size[1]
DAY III: Objective: Applying Lean to Construction			
• Getting to know fellow participants and facilitators			
3.0.0	Participants sign in + given name tags	15	plenary
• Simulation of Target Value Design			
3.1.1	TVD "spaghetti and marshmallow" game	90	plenary
• Examples of actual applications of Lean to construction			
3.2.1	Target Value Design (TVD) and its application to construction (Cathedral Hill case study)	60	plenary
3.2.2	Last Planner System of Production Control (various case studies)	45	plenary
3.2.3	Integrated Project Delivery (IPD) and its application to construction Owen Matthews paper case study + introduction to sample contracts	45	plenary
• Applying Lean to Penrose-St. Francis projects			
3.3.1	Discussion about how lean can be applied to Owner's projects, as facilitated by Owner	120	plenary
• Post-conference "final exam" and survey			
3.4.1	Post-conference (a) "final exam" confidence survey + (b) satisfaction survey	30	Plenary

[1] Definitions of *group size*:
"Plenary": Participants undivided (about 23 participants)
"Half groups": Participants divided into *two* groups (about 10-12 participants per group)
"Cluster groups": Participant divided into *four* groups (about 5-6 participants per group)

SURVEY INSTRUMENTS

To determine the effectiveness of the workshop design, participants were requested to complete a pre-conference survey on Day I (table 2, activity 1.0.3), and a similar post-conference "final exam" survey immediately after the workshop on Day III (table 2, activity 3.4.1). Additionally, a separate survey was administered to rate their satisfaction level with respect to each activity of the workshop, the venue, food, and whether or not they felt they could recommend the workshop to others. The latter survey included a blank "plus/delta" table for the lead facilitator and the three graduate student facilitators.

Participants were instructed to create a fictitious name and to write it in the upper right corner of the survey instruments so that their pre-and post-conference surveys could be paired and statistically analyzed, while still maintaining participant anonymity.

Participants were asked to respond to pre- and post-workshop survey instruments. Section A helped establish the extent of their prior exposure to lean concepts through The Toyota Way, which they had been asked to read before arrival at the workshop. Section B (Figure 1) tested them on their understanding of 21 lean construction

concepts by asking them to rate their perceived level of confidence of understanding along a Likert scale (from 1-5 where 5 represents the highest level of confidence). They were also asked to provide a concrete example of how they might apply the lean concept to their organizations.

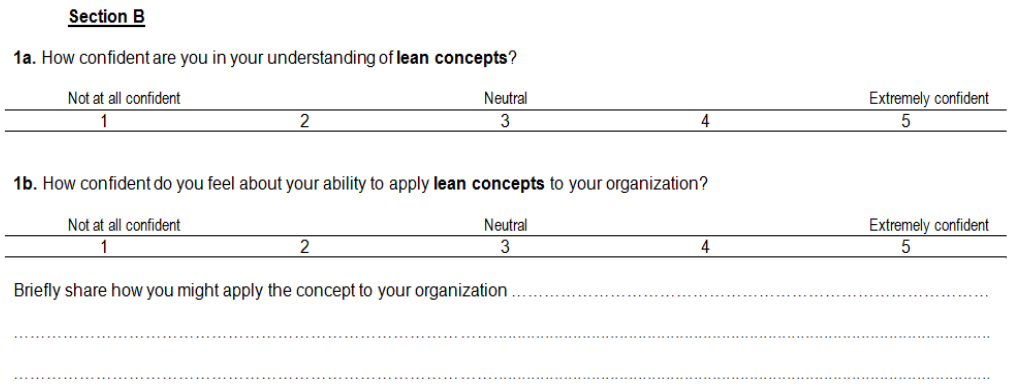
Table 3: Simulation exercises used to illustrate lean principles

Simulation Game	Purpose	Known originator OR rules taken from this citation	Developer of adaptation
Deming's Red Bead Game	Demonstrates that many problems are due to problems with the system rather than with problems with individuals	(Deming 1994)	Unrevised; used original version
Maroon & White Game	Demonstrates that greater overall gains can be achieved when a system, rather than parts, are optimized	(CSB-SJU 2012)	J. P. Smith
CII Alignment Exercise	Makes explicit and transparent priority differences between team players, for the purpose of discussion	(CII-POTF 2003)	Unrevised; used original version
Airplane Game	Demonstrates the impact of cell design, small batch-sizes (one-piece flow), push versus pull, and load leveling.	(Visionary Products Inc. 2007; Visionary Products Inc. 2008)	Unrevised; used original version
Dice Game	Demonstrates the impact of variability on schedule and cost	(Goldratt and Cox 1986; Tommelein et al. 1999)	Z. K. Rybkowski J. Hullum J. P. Smith
5S Game	Demonstrates the impact of application of 5S principles on time and morale.	(Drummond and Roberts 2012)	Unrevised; used original version
TVD Game	Simulates the Target Value Design process	Peter Skillman (TED 2012)	M. Munankami Aditi Kulkarni

RESULTS

Survey results were entered into Excel and a paired, two-tailed t-test performed to determine the statistical significance level of mean differences observed before and after the workshop. Because participants were asked to create a fictitious name for their surveys so we could match pre-surveys with post-surveys, we have confidence that the responses were relatively truthful.

Tabulation of survey results are shown in Table 4. We have highlighted the two concepts that represented the greatest extremes in mean difference between pre- and post-conference confidence rankings. Survey results from those who came for only one or two days and who did not attend the full three day workshop were not included in the calculations.



Section B

1a. How confident are you in your understanding of **lean concepts**?

Not at all confident		Neutral		Extremely confident
1	2	3	4	5

1b. How confident do you feel about your ability to apply **lean concepts** to your organization?

Not at all confident		Neutral		Extremely confident
1	2	3	4	5

Briefly share how you might apply the concept to your organization .....

.....

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Figure 1: Representative portion of pre-conference survey instrument.

Results from the separately administered post-conference satisfaction survey indicated that of all the games played, participants ranked the Airplane Game (μ=4.7, σ=0.75), the Dice Game (μ=4.6, σ=0.68) and the TVD Game (μ=4.6, σ=0.69) as the most effective, and Deming's Red Bead Game (μ=3.8, σ=1.32) and the CII Alignment Exercise (μ=3.7, σ=1.17), as the least effective, where μ represents mean and σ standard deviation of all responses. They also rated the two films, "The Easier Way" (μ=4.5; σ=0.69) and the W. Edward's Deming video (μ=4.5, σ=1.02) quite highly. Participants rated the workshop as mostly effective (μ=4.5, σ=0.61) and 83% of participants said they would recommend the workshop to others.

DISCUSSION

An assumption of this research is that the difference between pre- and post-conference survey ratings is a representation of learning that took place. We acknowledge there may be a natural tendency for participants to rate themselves more highly during the post-conference survey regardless of the actual learning that took place. We attempted to remove some of this bias by asking participants to create fictitious names for themselves.

We also acknowledge that some terms, such as "market cost," hold a vernacular meaning in industry, independent of the lean definition, and likely prompted participants to suggest that they had some understanding of the concept, even if the term has a slightly different connotation and application in lean. We chose to test only those concepts that were covered during the workshop.

Although responses varied from 0-100%, participants had read 56% of The Toyota Way, on average, prior to attending the workshop. This may help explain the result that many of the participants indicated they had some prior understanding of general lean concepts, as is shown by the mean pre-conference confidence score results shown in Table 4.

Table 4: Mean confidence scores for each lean concepts question and pre- and post-conference differences. Scores ranged from 1←→5, where 1 represented not at all confident in understanding the concept and 5 represented extremely confident.

		mean scores				
	Q #	**pre-**	**post-**	**difference**	**p-**	**df**
lean concepts	**1a**	3.1	4.0	0.96	2E-06	
	1b	2.6	3.7	1.07	2E-05	
Target Value Design	**2a**	2.5	3.7	1.24	8E-06	
	2b	2.4	3.5	1.15	1E-04	
Integrated Project	**3a**	2.9	3.8	0.91	2E-04	
	3b	2.6	3.5	0.88	4E-04	
flow	**4a**	3.1	4.3	1.17	7E-06	
	4b	2.5	3.8	1.29	5E-06	
kaizen	**5a**	2.4	3.8	1.31	6E-05	
	5b	2.2	3.5	1.34	2E-05	
reducing waste	**6a**	3.7	4.2	0.57	7E-03	
	6b	3.2	3.8	0.59	2E-02	
increased value	**7a**	3.1	4.0	0.86	2E-04	
	7b	2.8	3.6	0.80	4E-04	
cell design	**8a**	2.4	3.3	0.89	7E-04	
	8b	2.1	2.8	0.63	2E-02	
push versus pull	**9a**	2.9	4.3	1.33	1E-06	
	9b	2.7	3.9	1.20	2E-04	
reduced batch size	**10a**	2.7	3.9	1.25	7E-05	
	10b	2.3	3.3	1.00	1E-03	
multi-tasking*	**11a**	3.5	4.0	0.54	6E-03	
	11b	3.3	3.7	**0.37**	6E-02	22
one-piece flow	**12a**	2.4	3.6	1.16	7E-05	
	12b	2.0	2.8	0.71	3E-04	
load leveling	**13a**	2.6	4.3	1.71	1E-08	
	13b	2.2	3.3	1.09	8E-05	
5S	**14a**	2.0	4.0	**2.02**	2E-07	22
	14b	1.9	3.7	1.81	7E-08	
alignment	**15a**	2.3	3.4	1.16	7E-05	
	15b	2.1	2.9	0.80	4E-03	
variability	**16a**	2.2	3.5	1.36	5E-06	
	16b	2.0	3.1	1.15	3E-06	
Toyota Way principles	**17a**	2.7	3.9	1.17	5E-06	
	17b	2.3	3.3	0.93	3E-04	
market cost	**18a**	2.5	3.6	1.09	2E-04	
	18b	2.3	3.1	0.81	3E-03	
allowable cost	**19a**	2.3	3.6	1.32	2E-05	
	19b	2.2	3.1	0.99	5E-04	
market cost	**20a**	2.5	3.9	1.36	8E-06	
	20b	2.3	3.7	1.35	6E-05	
pain-sharing/	**21a**	2.4	3.9	1.50	2E-06	
gain-sharing	**21b**	2.1	3.1	0.94	8E-05	

*The term "multi-tasking," instead of "multi-skilling" was erroneously printed in the survey.

It is interesting to note that statistical analysis of the results indicate that participants felt more confident in their understanding of all 21 concepts (part a; statistically significant to a 95% level; $p<=0.05$). It is also interesting to note that standard deviations for those games ranking the highest in the satisfaction survey were relatively low while those games ranking the lowest had relatively high standard

deviations, suggesting there was general agreement with respect to games ranked highest and a diversity of opinion with respect to games ranked the lowest. Finally, when asked to note practical applications of the specific lean principles (part b), participants could name twice as many practical applications post-workshop versus pre-workshop (Average 8.59/21 post versus 4.58/21; p=0.014). The greatest improvement in naming practical applications was with "push vs. pull," "load leveling," and "5S"—a result which is, perhaps, not surprising since the airplane game clearly illustrates the first two concepts and the 5S game clearly illustrates the latter.

CONCLUSIONS

Participant suggestions made during the "plus/delta" sessions at the end of each day provided valuable opportunities for improvement in our workshops. We concluded that although the current teaching process showed positive results in participants' understanding of the principles, a few key changes were necessary.

Participants, in general, felt that a combination of Day I and Day II would allow for better understanding of the Toyota Production System (TPS) principles at the same time as it would create a better flow on both days. It was suggested that half of the games be played on Day I, with their corresponding TPS principles being discussed immediately following completion of the game, and the other half be played and discussed on Day II. It was also evident that OAEC industry participants are more likely to benefit from summary sheets for each principle than from having to read an entire book. Apparently a number of participants did not appreciate feeling like a student again.

We recognized that efficiencies could be gained in both the Airplane Game and the Dice Game due to their comparatively intensive set-up times. Procurement of additional rooms or the strategic scheduling of those two games would have prevented some wasted time. We also concluded that a reallocation of time in favor of current industry applications (i.e., Last Planner System, TVD, IPD) would also meet the demands of industry learners more effectively.

Overall, the workshop appeared relatively effective at increasing the participants' understanding of key concepts relating to lean, TVD, and IPD. However, it is also clear our workshop materials need to be subjected to further rounds of continuous improvement.

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