COLLECTIVE KAIZEN AND STANDARDIZATION: THE DEVELOPMENT AND TESTING OF A NEW LEAN SIMULATION

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ABSTRACT

Simulations can offer a laboratory-like environment for controlled experimentation, as well as immediate and convincing proof of the effectiveness of specified lean principles. At the heart of lean thinking resides the concept of *kaizen*—or continuous improvement—and standardization, conducted within a culture of respect. Effective use of collective kaizen and standardization capitalizes on the ability of individuals to innovate, to learn from one another, and to improve their effectiveness, thus helping managers improve time, cost, quality, safety and morale by engaging the employees they already have.

Despite the role of collective kaizen and standardization as seminal to the very definition of lean thinking, there is no existing published lean construction simulation that focuses exclusively on the concept of collective kaizen and standardization. This paper reports on the development and testing of a lean simulation that focuses on collective kaizen and standardization. The simulation was developed by students as the final project for a US-based university lean construction course consisting of upper-level undergraduate and graduate-level construction science students. The simulation was inspired by primary source writings of early twentieth century American psychologist and industrial engineer Lilliane Gilbreth and efficiency engineer Frederick Winslow Taylor, and introduces simulation participants to the critical concepts of collective kaizen and standardization. The simulation has been tested during three semesters of courses dedicated to lean construction at the originating university, at two additional US universities, and at two international-level lean construction and quality control conferences. Modifications have been made based on preliminary feedback.

KEYWORDS:

Lean simulation, kaizen, continuous improvement, standardization

INTRODUCTION

COLLECTIVE IDEATION AS PART OF LEAN'S CULTURE OF RESPECT AND KAIZEN

Lean simulations or serious games afford an opportunity to test new ideas within the relatively risk-free containment of first run studies, as well as to develop "buy-in" from those who will eventually need to apply lessons of lean principles to actual

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building projects. One lean principle—that of collective kaizen and standardization—is fundamental to the very nature of lean thinking. In Rybkowski et al. (2013), the process of continuous improvement and periodic, regular, standardization was graphically represented. The concept of continuous improvement (e.g. *kaizen*) and periodic standardization may seem intuitively obvious, but the way the improvement is made may not be similarly intuitive. The culture of respect fundamental to lean thinking demands that kaizen is not undertaken autocratically by a few individuals in a back room, but rather collectively, transparently, generously and openly with top level management, as well as with those who are most familiar with the actual work involved (Berger 1997; Glover et al. 2012). The term "kaizen event" is often used and has been defined as "a focused and structured improvement project, using a dedicated cross-functional team to improve a targeted work area, with specific goals, in an accelerated timeframe" (Farris et al. 2008). Liker (2004) describes the Japanese understanding of kaizen which includes self-reflection, self-criticism and an intense desire to improve. It should be acknowledged that kaizen events (Glover et al. 2012) are generally communal in nature and so the adjective "collective" describing the term "kaizen" may seem redundant. Nevertheless, the authors of this paper wish to reinforce the notion that continuous improvement in lean construction *must* be a collaborative effort. This is because the knowledge required to effectively design and construct a building is far greater than that possessed by any one individual.

The lean construction community often cites the expression that "with every pair of hands comes a free brain" (Alan Mossman, personal communication, as quoted by Tariq Abdelhamid 2012). Adler (1999) described the Toyota Way culture upon which Lean thinking is based as "democratic Taylorism" (Liker 2004, p. 145). The second tier of the "4 P" model of the Toyota Way is entitled "People and Partners" and subtitled with the directive "Respect, Challenge and Grow them" (Liker 2004, p. 6, figure 1-1). Embedded as words in the pediment of the house of lean (Liker 2004, figure 3-3, p. 33)—The Toyota Production System—are five expected outcomes from effective implementation, one which includes "high morale."

THE NEED FOR STANDARDIZATION

Continuous improvement is intended to be continuous. However, continuous improvement also demands periodic standardization or stabilization (Liker 2004). As Gilbreth noted in 1914, "Chances for invention and construction are provided by standardization. By having a scientifically described standard method as a starter, the worker can exert much of his mental power toward improvement from that point upward, instead of being occupied with methods below it and in wasting, perhaps, a lifetime in striving to get up to it" (p. 179). "Standardization conserves individual capacity by doing away with the wasteful process of trial and error of the individual workman. It develops individuality by allowing the worker to concentrate his initiative on work that has not before been done, and by providing incentive and reward for innovations" (Gilbreth 1914, p. 149). Of course, as Gilbreth (1914) states, "a standard is progressive" —[it] "remains fixed only until a more perfect standard replaces it" (p. 140). Similarly, according to Imai (1986), no process can be improved without standardization: "Lasting improvements can only be achieved if innovations are combined with an ongoing effort to maintain and improve standard performance levels (Imai 1986, p. 6-7). Liker (2004) echoes this: "If a process is shifting from here to there, then any improvement will just be one more variation that is occasionally used and mostly ignored. One must standardize, and thus stabilize the process, before continuous improvements can be made" (Liker 2004, p. 142).

The question still remains on how to bring the majority of workers to a level at which they should be operating. Both Taylor (1947, p. 55) and Gilbreth (1914, p. 152) refer to certain individuals as "first-class men" and sometimes as "high-priced men" (Taylor, p. 44-45). Although these expressions are mentioned for historical reasons, the simulation will instead use a gender neutral term and refer to such individuals as "first-rate performers". "The manager notices some particularly successful man, or method, or arrangement of tools, equipment or surroundings, and decides to have a record made thereof that the success maybe repeated" (Gilbreth 1914, p. 143). Again, Gilbreth is cognizant that worker creatively should be part of the continuous improvement process. She writes: "Perhaps one thing that makes the typical 'Systems' so attractive is the personal note that they contain. Illustrated with pictures of successful work that the workers themselves have done, often containing pictures of the men themselves that illustrate successful methods, with mention of the names of men who have offered valuable suggestions or inventions, they make the worker feel his part in successful results" (Gilbreth 1914, p. 146).

The periodic integration of kaizen events, improvement and standardization within a culture of respect are graphically represented in **Figure 1**. The figure echoes Berger's (1997) words: "the Japanese kaizen is argued to be inseparable from maintaining standards since this relation is one of the very foundations for claiming that small ongoing improvements can accumulate to an overall contribution to organizational performance" (p. 111).

SIMULATIONS, GAME THEORY, AND SERIOUS GAMES

The transferring of lean manufacturing principles between lean veterans and lean novices enjoys a tradition of teaching via simulations, serious games, and game theory (de Carvalho et al. 2013; Pourabdollahian et al. 2012; Susi et al. 2007; Verma 2003). Lean construction theorists use simulations, serious games, and game theory not only to impart lean lessons, but to investigate and/or quantify the potential impact of specific lean interventions (Rybkowski et al. 2008; Rybkowski et al. 2011; Rybkowski et al. 2012; Sacks et al. 2007; Smith and Rybkowski 2013; Tommelein et al. 1999). Simulations or games also offer the statistical power and experimental certainty afforded by randomized controlled trials that are common in the field of medical research but almost non-existent in the field of construction management research where a case study research offers a statistically meager sample size of N=1 (Rybkowski et al. 2008). While simulations or games may not perfectly duplicate reality, they can approximate it, and like randomized controlled trials, they isolate a single variable to approximate its impact when measured against a control group. Naturally, both internal and external validity need to be established in order for a game to accurately inform an actual construction process (Jackson 2012, Leedy and Omrod 2010). Nevertheless, one advantage to using simulations or games is that they permit experimentation on a limited scale so that an innovation can be tested first—and its impact contained and assessed—before it is applied to an actual (and often costly) construction project. This paper reports on the development and testing of a new simulation or serious game. The simulation was designed to investigate and inform participants about the importance and potential impact of collective kaizen and standardization within the lean construction process.

METHODOLOGY

The purpose of the simulation is to model the process of continuous improvement and standardization to participants so these concepts can serve as a prelude to brainstorming opportunities for improvement to actual construction processes.

During the fall semester of 2012, students in an upper level undergraduate lean construction course at Texas A&M University were grouped into teams and

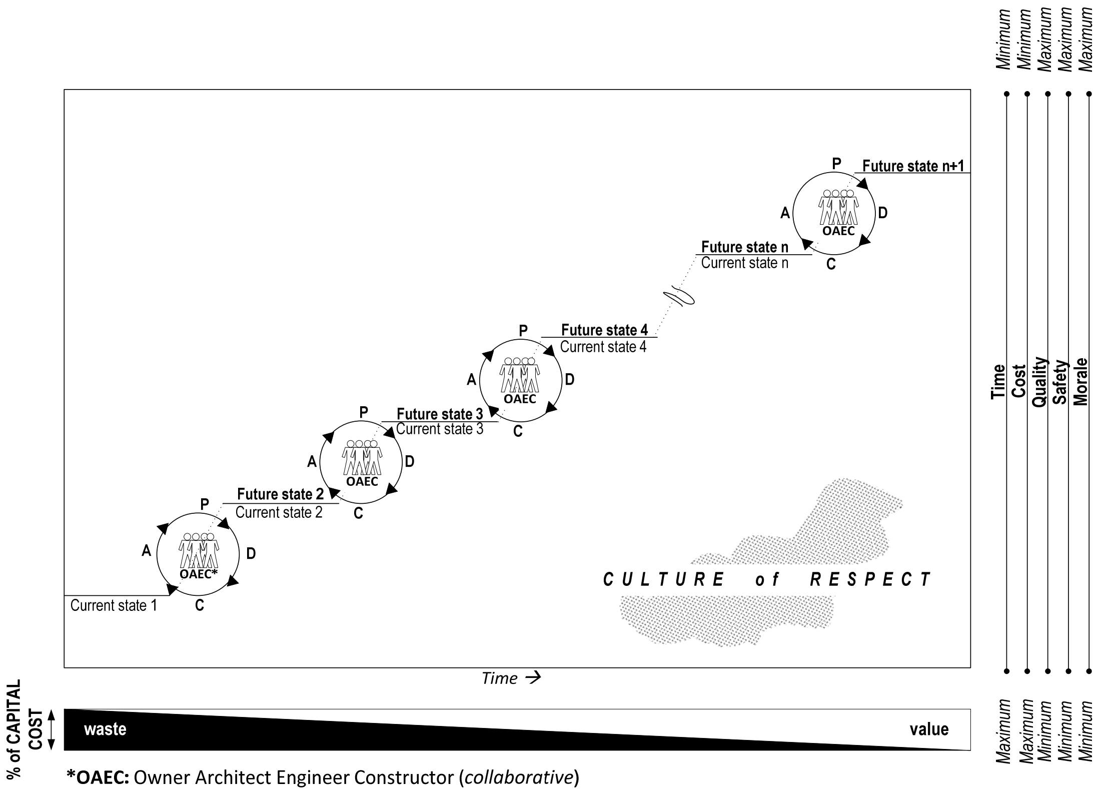

Figure 1: The continuous improvement process of lean construction (after Rybkowski et al. 2013, Figures 4 & 5, p. 88).

challenged to identify a lean principle, and then to design a portable simulation to illustrate and test that lean principle for their final course project. One team of five students (Karteek Kuncham, Travis Arnold, Shashank Tiwari, Florencio Maya, and Sean O'Shea) developed a simulation to illustrate the concept of collective kaizen and standardization. The simulation was tested with participants in the class, and subsequently at two international-level conferences (the 2013 World Conference on Quality and Improvement: Indianapolis, Indiana, on May 6, 2013; and the Lean Construction Congress, Dallas, Texas, on October 23, 2013) and as part of two non-Texas A&M university classes on lean construction. The simulation has been adjusted to accommodate recommended changes. Adjusted rules for the simulation are described below.

To play the game, the following are needed:

- One facilitator and multiple participants
- Desk tops on which participants will fold paper airplanes
- Photocopies of 7” of a ruler (one per participant or table of participants)
- Tape measure or yard stick
- Masking tape or post-it notes to mark the starting line on a floor for launching paper airplanes as well as to mark every two feet along a corridor
- 8 1/2” x 11” (or A4) pieces of pre-used scrap paper (to avoid waste of virgin paper stock)
- CD with song “Eye of the tiger” by rock group Survivor®, or access to internet version of song, and CD player or laptop with speakers to play song
- Stopwatch

The facilitator instructs participants to make a 7” long paper airplane in three minutes or less, to the tune of Survivor’s “Eye of the Tiger.” Although there is no meaningful link between the selected music and the objective of the simulation, the piece was chosen by the student inventors and has been retained out of respect for their vision. Most importantly, the music helps generate a festive, playful atmosphere among participants. The facilitator announces that the objective of the game is to have participants make a paper airplane fly as far and as straight as they can. However, participants are *not* permitted to pre-test their airplanes during the development process. The facilitator consults a stopwatch to arrest the music after three minutes, and then instructs participants to write their initials on their respective planes. At this point, participants are invited to line up at the starting line and, one-by-one, test-fly their airplanes.

The plane that travels the farthest and the straightest is declared the winner. Note that the winning participant should be requested to fly his or her airplane again to ensure the result is repeatable (otherwise the next farthest repeatable airplane is instead declared the winner). Also, if two or more participants have designed airplanes that fly approximately similar distances, they should both re-test their airplanes AND count the number of folds used to construct their planes. If two or more airplanes fly a similar distance, the participant who designed the airplane requiring the *least* number of folds is declared the ultimate “first-rate performer.”

The first-rate performer is then invited to share his or her airplane folding strategy with all participants. He or she is to walk the room and ensure that all participants mimic his or her folding process with a new sheet of scrap paper. Once all participants have had a chance to practice folding airplanes according to the improved process recommended by the “first-rate performer,” the facilitator starts the music and, once again, gives participants three minutes to create a standardized plane—this time based on the folds recommended by the first-rate performer. Finally, participants write initials on their airplanes and test-fly them in the same measured corridor.

RESULTS

The game was field-tested three times at the originating university, at two international conferences, and at two universities external to the originating university. Results varied somewhat depending on the numbers of participants and modifications made to the simulation at the time of play. Case study results from a playing of the most mature version of the game are reported here.

Figure 2 photographically captures the variety of paper airplanes constructed during the first, or "pre-" round of play, as well as the second, or "post-" round of play. To generate their designs in the post- round, participants followed the folding patterns of the winning plane (Participant Q in **Figure 2**). Note that participant Q's airplane design has been standardized during this round.

In **Figure 3**, participant pre- and post- flight travel distances were captured and arranged according to increasing levels of improvement. Performance by participant Q—the "first-rate performer" is marked with a star. Note the flight performance of airplane by participant Q is consistent during both pre- and post- rounds of play.

Because the flight testing corridor floor had been marked with post-it notes every two feet, participants were able to personally record the distance their airplanes had travelled during both the pre- and post- flight tests. It is notable that participant E had a very long pre-round distance (20 ft) and that his post-round distance with the standardized airplane was even farther than the original Q distance. This might suggest that E had a superior throwing skill which was not measured. Because several planes in the post-round went farther than the original Q distance, even though the planes were merely copies of Q, this might suggest an overall improvement in throwing skill in the post-round that was not specifically measured.

A table showing pre- and post- results is shown in **Table 1** and graphically represented as a box-and-whisker plot in **Figure 4**. Note that the mean travel distance during the pre-round test was 6.8 ft; during the post-round test the mean travel distance was 22.7 ft.—a 233% improvement. Similarly, difference in *median* (versus mean) travel distance improved from 6 ft. to 22 ft. —a 267% improvement. Although after standardization of design there was a tightening of performance (reduction of variability is a critical success criterion in six-sigma quality improvement), in this instance, the dispersion of data in the pre-round was actually quite small. If the "outliers" of 27 and 20 feet are removed, the remaining airplanes performed consistently poorly, with a small standard deviation of 2.3. In other words, although the post-round performance was consistently high, the pre-round performance was also consistently low (*As an aside:* Despite the rumored, common childhood experience of throwing paper airplanes during one's school years, we discovered that very few people actually know how to decently fold and throw a paper airplane!)

DISCUSSION

The primary purpose of this simulation has been to illustrate the foundational lean concept of continuous improvement and standardization. Although the simulation demonstrated one round of improvement and standardization, the intention is to demonstrate the first of multiple rounds of future play. If time permits, the facilitator can organize a second collective kaizen event so that additional recommended improvements—and subsequent standardized models—can be made.

The question of frequency of improvement and standardization inevitably arises. Ideally, one should replace a standard as soon as an improved future state is revealed. In practice, the issue may be more complex. For example, one might ask: how often can standards be changed without creating confusion among those who implement the standards? Also, at what point should incremental improvement be replaced with far more dramatic disruptive change?

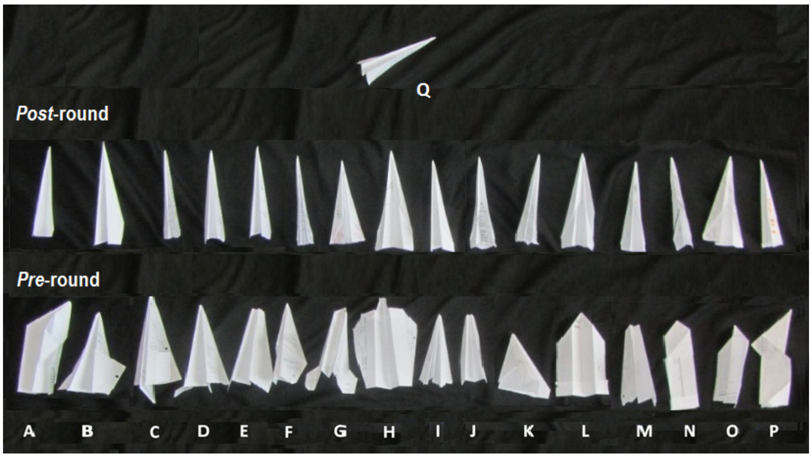

Figure 2: Example of paper airplanes generated by simulation participants before ("pre-round") and after ("post-round") implementation of collective kaizen and standardization. Airplanes are labeled according to participant identification codes, A through Q. Airplane Q was designed by the "first-rate performer" and served as the model standard for participants A to P to follow during the "post-round" of play.

One of the great lessons of the game is that it challenges the tendency for managers to assume productivity solutions lie in resources external to their company (e.g. if only we had more intelligent or productive employees working for us, or, if only we had the resources to hire external consultants, etc., we could be more competitive as a company). Contrary to this tendency of belief, substantially improved performance is achieved during the simulation with employees an organization already has in its employ.

Sometimes no spectacular performer arises during playing of the game. However, it should be remembered that lean thinking celebrates small incremental improvements. It matters not that the improvement may be relatively insignificant. What matters more is that regular opportunities be given for employees who actually perform a front-line task to have their performance measured, and that the best-performing processes be given an opportunity to be shared and standardized by others in the company. One basic underlying assumption of lean thinking is that, by nature, most human beings are intelligent and creative and that, because a job well done brings satisfaction, most individuals *want* to perform well.

Other questions certainly remain. For example, how can managers incentivize high performing individuals to share their secrets of success with co-workers? In lean lingo, the expression "open kimono" is used. Bringing individuals together and collectively rewarding them to achieve a common goal—while still appropriately recognizing the achievement of that individual—may be the high-wire act of the lean manager. While this simulation of collective kaizen and standardization offers suggestions on ways construction managers can improve productivity and morale within their own organizations, we also acknowledge that when the metaphorical lid of this simulation box is opened, some challenging questions may emerge.

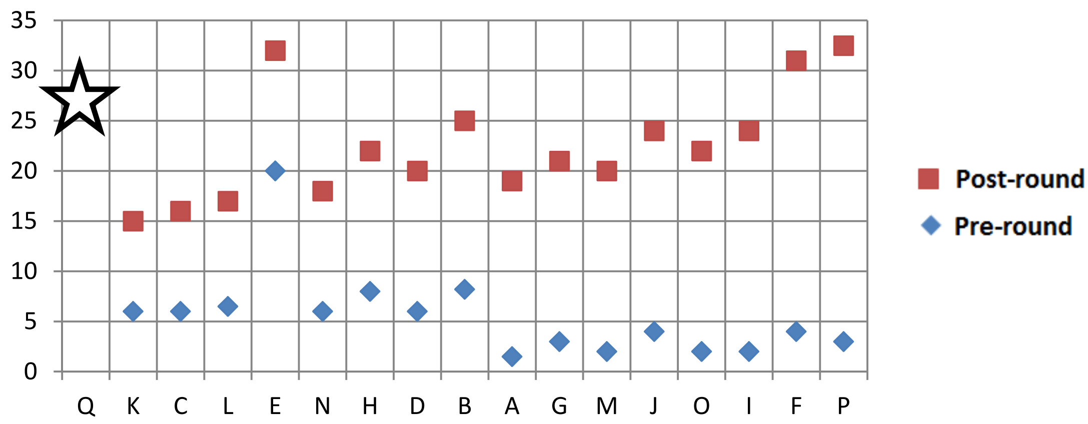

Figure 3: Pre-round and post-round flight performance of paper airplanes arranged by increasing levels of performance improvement. Pre-round- and Post-round flight distance by participant Q—the "first-rate performer"—is indicated by a star.

For example, in his 1909 book, *Bricklaying System*, Frank B. Gilbreth details the myriad process innovations that led to early success in the bricklaying business. In their book, *Cheaper by the Dozen*, his children, Frank B. and Enestine (Gilbreth and Gilbreth Carey 1963) describe the initial resistance the young and precocious apprentice bricklayer received from his foreman. Evidently Gilbreth "made so many suggestions about how brick could be laid faster and better that the foreman threatened repeatedly to fire him" (Gilbreth and Gilbreth Carey 1963, p. 35). Yet Gilbreth, ever observant and determined, explained to the foreman: "did you ever notice that no two men use exactly the same way of laying bricks?...It's important because if one bricklayer is doing the job the right way, then all the others are doing it the wrong way…I'd find who's laying brick the right way, and make all the others copy him" (Gilbreth and Gilbreth Carey 1963, p. 36). Gilbreth designed a scaffolding that gave him—and then other craftsmen—an exceptional level of productivity that was previously unknown. Gilbreth became his own contractor, and according to his children, by the age of twenty-seven, had offices in Boston, New York, and London, smoked expensive cigars, and even owned his own yacht.

Eventually even the stubborn foreman copied Gilbreth's methods and in so doing, improved the bricklaying productivity of his own men. Yet the resistance Gilbreth experienced is familiar to anyone who works in the construction industry. Why, we might ask, is there such unwillingness for superiors to acknowledge intelligent process recommendations if they come from subordinates? What would it take to transform a foreman from one who sees his or her role as a stern task master (no matter how unproductive or illogical those commands may actually be) into one who promotes a culture of innovation and a flourishing of ideas?

Table 1: Pre-round and post-round testing of paper airplane flight yielded a 233% improvement in mean distance.

ID	Pre-round (ft.)	Post-round (ft.)	Improvement (ft.)
A	1.5	19.0	17.5
B	8.2	25.0	16.8
C	6.0	16.0	10.0
D	6.0	20.0	14.0
E	20.0	32.0	12.0
F	4.0	31.0	27.0
G	3.0	21.0	18.0
H	8.0	22.0	14.0
I	2.0	24.0	22.0
J	4.0	24.0	20.0
K	6.0	15.0	9.0
L	6.5	17.0	10.5
M	2.0	20.0	18.0
N	6.0	18.0	12.0
O	2.0	22.0	20.0
P	3.0	32.5	29.5
Q	27.0	27.0	0.0
Mean	**6.8**	**22.7**	**15.9**
Standard Deviation	**6.8**	**5.4**	**7.0**
Median	**6.0**	**22.0**	**16.0**
Maximum	**27.0**	**32.5**	**5.5**
Minimum	**1.5**	**15.0**	**13.5**

CONCLUSION

The heading for Principle 6 in *The Toyota Way* reads: "Standardized tasks are the foundation for continuous improvement and employee empowerment" (Liker 2004; p. 140). In one phrase, the phrase succinctly captures the key objectives of this innovative simulation.

This paper documents the methods and expected outcomes for a new simulation that illustrates the productivity potential of collective kaizen and standardization, addressed by Principle 6 of *The Toyota Way*. The intent of the simulation is to: educate those who are first being introduced to the principles of collective kaizen and standardization in lean construction and create buy-in among workers who will be implementing lean construction. But it is also hoped the simulation may serve as an experimental framework to investigate how collective kaizen and standardization can be made part of the daily process fabric of lean construction processes.

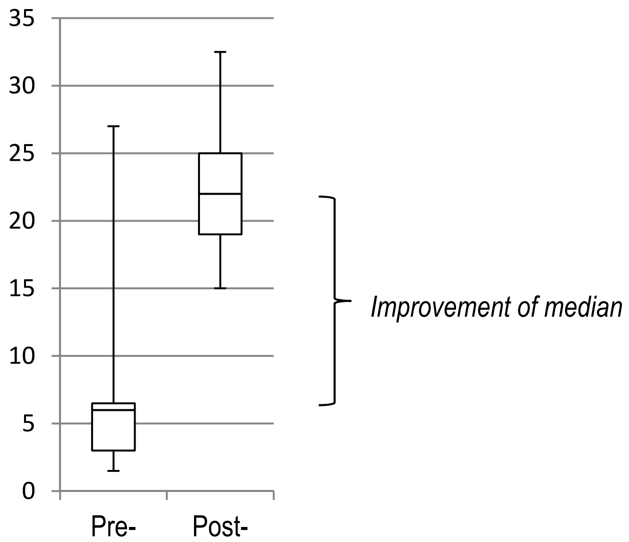

Figure 4: A box-and-whisker quartile plot of participants' performance shows a median improvement from Median=6 to Median=22—a 267% improvement. Also note the tightened consistency of performance, as indicated by the drop in spread.

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