

Video-based objective measurement of problem-solving process quality in kaizen teams

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Abstract

The outcome of a kaizen event is assumed to depend on the quality of its internal problem-solving process. Thus, we developed a more objective measure. Each team member's remarks during 21 video-recorded events were categorized into the six commonly defined problem-solving phases. The process data was graphically plotted vis-à-vis theoretically ideal phases. Ten kaizen experts then rated these 21 graphs in terms of internal process quality. We also calculated plausible quantitative measures. Stepwise regression analysis pointed to the 'total squared value of jumps' as the best predictor of high internal process quality.

Keywords: Lean/Kaizen, Measuring process quality, Structured team problem-solving

Introduction

Problem solving skills are considered to be critical in the 21st century (World-Economic-Forum, 2018). However, *team* problem-solving, including kaizen, often fails among the innumerable teams worldwide, trying to solve problems on a daily basis (Bessant *et al.*, 2001). Since kaizen problem solving is a deliberate and disciplined way of handling persistent efficiency issues, this paper aims to contribute to its lived-up potential. A kaizen event involves a multidisciplinary team attempting to solve recurring work problems through a set of consecutive phases, including problem definition and root-cause analysis (Farris *et al.*, 2009; Glover *et al.*, 2014; Woods, 2000). Each phase must answer specific questions before moving to the next phase (Liker, 2004). Such *structured* problem solving mode is widely seen as the most effective way of solving a problem as a team (Mohaghegh and Grössler, 2019), and upheld by the state-of-the-art small group and team field research on team performance, e.g. group effectiveness (Hackman and Morris, 1975), group composition (Kozlowski, 2015) and creative problem solving (McFadzean, 2002). Team research is strongly influenced by McGrath's input-process-output heuristic approach (Ilgen *et al.*, 2005).

Although it is universally acknowledged that team processes are inherently dynamic, most academic researchers often consider them to be static (Kozlowski, 2015) without examining the effectiveness characteristics (Cronin *et al.*, 2011). The same holds for the internal process of a kaizen event, which is often studied as a whole (Farris *et al.*, 2009) and the different iterative sub phases are disregarded.

Moreover, studies of kaizen events and other contexts of group problem solving tend to only rely on subjective self-reports of internal process quality, such as the one offered by Farris *et al.* (2009). A better understanding of the characteristics of an effective internal process of kaizen events, and a more objective judgement of process quality based on real-life observations, would offer opportunities to improve problem-solving team processes and, in turn, team performance. To ultimately improve the quality of this type of internal team process, we used a “high-resolution” video method (Kozlowski, 2015, p. 278) and combined it with expert interviews to address the question: *How can we determine the quality of the internal process of team-level structured problem solving events more objectively?*

The Theory section explains the different research areas we integrated to build a more objective measure of internal process quality. The Methods section describes how we developed the new measure: combining real-life video observations with expert opinions and statistical analyses. The Results section shows how a solid kaizen event process quality indicator is derived. Then, theoretical, practical and future-research implications are drawn up.

Theory

This study is grounded in an array of academic fields from: Operations Management kaizen literature; small group (creative) problem solving research, guided by Organizational Behaviour theory; and mathematical process quality indicators.

In Operations Management, kaizen is defined as “a structured project performed by a multi-disciplinary team to improve a targeted work area or process in a given timeframe” (Bortolotti *et al.*, 2018, p. 555). Kaizen events may vary in length and consist of one or more meetings (Glover *et al.*, 2014). Many scholars used the Farris *et al.* (2009) model to study the determinants of kaizen event outcomes (Álvarez-García *et al.*, 2018) from . One of those determinants concerns the internal process (Farris *et al.*, 2009), operationalized as the extent to which kaizen team members feel that open communication took place in the team and respect member’s unique and diverse contributions, opinions and feelings. Liu *et al.* (2015) found the internal problem-solving process itself might inhibit the kaizen process. These studies used subjective or biased measures as variables; none of them focused on a more objective understanding of the constituents of an optimal internal kaizen process or the behaviours involved in high team-process quality.

To attain high kaizen effectiveness, the event has to be conducted through certain ordered problem solving phases (Kepner and Tregoe, 1965; Liker, 2004). ‘Ordered’ means that the team, after reaching consensus about the result of a phase, continues to the next phase, without having to return to a previous one. Structured problem solving, like kaizen, has the following phases (Woods, 2000): 1) problem definition; 2) root cause analysis; 3) idea generation; 4) plan implementation; 5) implement; and 6) check and sustain. A recent literature review showed that studies of this phased approach are rare (Franken *et al.*, 2019).

Most (kaizen) team studies have relied on surveys, which bias insights and thereby block the progress to optimal team performance (Kozlowski, 2015). Franken *et al.* (2019) suggested that, to be able to measure the kaizen process more objectively, participants’ remarks in a real-life video of a team performing kaizen must be coded to one of the six

kaizen phases. The events occurring over time can be represented graphically as sequential data points (similar to Kepner and Tregoe, 1965), (see, Figure 1).

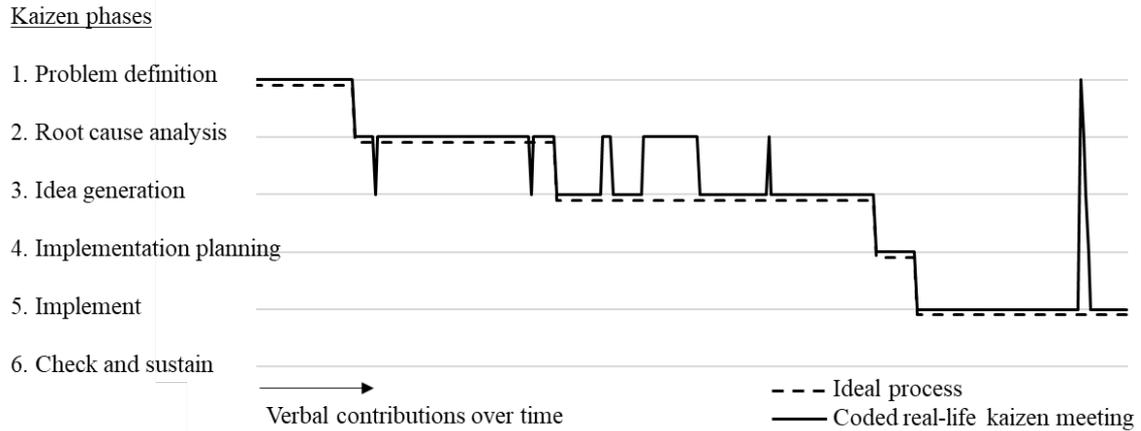


Figure 1 –Ideal Kaizen Internal Process and Coded Real-life Kaizen Meeting visualized

To interpret such graphs in an objective way, one could turn to the field of Applied Mathematics. The *model-fit theory* can be used to measure possible internal process quality (IPQ) indicators by counting the size of deviations vis-a-vis an ideal desired outcome (Meijer, 1994). Hence, to establish the IPQ of kaizen events, one may want to engage in counting the number of ‘jumps’ from one phase to another, in addition to the number of phases that are skipped when jumping from one phase to another (here called jumps > 1) as well as assign a logical value to each jump, i.e., the number of phase transitions crossed in a jump. Additionally, the *method of least squares* can be used to determine the best fit to a line of data (Miller, 2006), by calculating squared deviations. We used the method to determine the best fit between the given actual kaizen IPQ indicators, calculated through measuring the ‘jumps’ and the average of the experts’ opinions. As quality might be influenced by both the length (Cohen *et al.*, 2011) and the number of remarks, ratio indicators were also considered. Table 1 summarizes the possible IPQ indicators and the corresponding hypotheses one could examine.

Table 1 – Possible Quantitative Indicators of Internal Process Quality (IPQ) of Kaizen Events

| Indicator | Function | Hypothesis |
|-------------------------------------|---|--|
| 1. Number of jumps > 1 | Count (jump value > 1) | The number of phase-skipping jumps is negatively related to IPQ |
| 2. Total value of jumps > 1 | $\sum abs(\text{jump value} > 1)$ | The total-value of phase-skipping jumps is negatively related to IPQ |
| 3. Total squared value of jumps > 1 | $\sum (abs(\text{jump value} > 1))^2$ | The total-squared-jump-value of phase-skipping jumps is negatively related to IPQ |
| 4. Ratio of number of jumps > 1 | $\frac{\text{total number jumps} > 1}{\text{total number of verbal contribution}}$ | The ratio number of phase-skipping jumps and number of verbal remarks is negatively related to IPQ |
| 5. Ratio squared value of jumps > 1 | $\frac{\text{total squared value jumps} > 1}{\text{total number of verbal contribution}}$ | The ratio of total-squared value of phase-skipping jumps and number of verbal remarks is negatively related to IPQ |
| 6. Total value of jumps | $\sum abs(\text{jump value between contribution})$ | The total jump value is negatively related to IPQ |
| 7. Total squared value of jumps | $\sum (abs(\text{jump value between contribution}))^2$ | The total squared-jump-value is negatively related to IPQ |

| | | |
|--|--|---|
| 8. Ratio of total squared value of jumps | $\frac{\text{total squared value of jumps}}{\text{total number of verbal contribution}}$ | The ratio of total-squared-value of jumps and number of verbal remarks is negatively related to IPQ |
|--|--|---|

Methods

Ten kaizen experts reacted during individually held interviews to the 21 graphical representations of the systematically coded team members' video-based remarks during kaizen meetings (Franken *et al.*, 2019). Most of the graphs represented the first meeting of a kaizen event; in the remainder of this paper, we refer to them as kaizen meetings. Average experts' ratings of the IPQ were examined with the eight IPQ indicators (Table 1) to explore the predictive value of each indicator.

Expert sampling procedure and sample

The homogenous purposive sampling method (Etikan *et al.*, 2016) was used to select a group of ten kaizen experts with the following criteria: 1) At least five years of practical experience of kaizen or structured problem-solving events; 2) experience of multiple kaizen event roles (e.g., participant, facilitator, trainer or sponsor), and thus knowledge of the great variety of possible team processes; and 3) kaizen experience in different sectors, so as to be able to discuss possible problem-solving process differences across contexts. Pragmatically, Dutch experts were selected from the authors' wide business network. Table 2 describes the experts' characteristics.

Table 2 – Kaizen Expert Characteristics

| No. | Current position | Gender | Kaizen experience (years) | Current sector | Sectors in which the respondent has applied kaizen |
|-----|---|--------|---------------------------|------------------|---|
| 1 | Continuous Improvement process manager | F | 5 | Higher education | Higher Education, Educational Logistics |
| 2 | Lean programme manager | M | 9 | Healthcare | Education, Healthcare, IT |
| 3 | Lean and Agile consultant | F | 14 | Consultancy | Production, Sales and Marketing, R&D, Finance |
| 4 | OpEx Leader | M | 14 | Production | Energy, Production |
| 5 | Circular economy consultant | F | 15 | Consultancy | Production (Food, FMCG, Technical Components), Energy, Services |
| 6 | Lean and Agile team coach | M | 15 | Consultancy | Services, Finance |
| 7 | Director of Supply Chain and Operations manager | M | 20 | Production | Production, FMCG, R&D, Sales and Marketing |
| 8 | Change advisor | M | 20 | Consultancy | Production, Energy, Services |
| 9 | Departmental program lead infrastructure | M | 25 | Semi-government | Production, Services |
| 10 | Continuous Improvement programme manager | F | 30 | Higher education | Chemical Engineering, Production, Higher Education |

Expert interview

We sent the 21 graphical representations of the kaizen meetings to each expert before the interview, for familiarisation purposes. Each interview lasted, on average, 1.5 hours and was structured as follows: After an introduction, we explored the expert's generic perceptions of (effective) structured problem solving or kaizen with two questions: "What

is kaizen for you?” and *“If you teach people to do kaizen, what do you emphasize?”* Then, we asked them to think aloud (Van Someren *et al.*, 1994) whilst reviewing four graphical representations of four very different kaizen meetings. Some of these four examples had, clearly, visible kaizen phases and others were bumpier, with seemingly structured and/or skipped phases. We asked the experts to rate those graphs according to three elements: the overall process, the extent to which the approach was structured, and the expected valuableness of the kaizen meeting’s solution (e.g., *“To what extent do you expect this team to come to a valuable countermeasure?”*) (Likert scale 1-7, very poor to very strong). Next, we asked them to judge the IPQ of the 21 process graphs on a scale from 1 (absolutely inadequate) to 10 (perfectly adequate). We also queried them about the potential value of our method of graphical representation. With their permission, the interviews were audio-recorded.

Calculation of quantitative IPQ indicators

We calculated eight indicators of IPQ following the functions in Table 1. A jump was counted whenever the graph showed a transition between kaizen phases. When a remark jumped to a prior or next phase, a value of +1 was added to the total number of jumps. Each jump received a so called jump value, depending on the phase transitions that were made. For example: a jump from phase 1 to phase 2 receives the jump value 1; a jump from phase 1 to phase 3 receives the jump value 2, a jump from phase 4 to phase 2 receives the jump value -2, etcetera.

Data analysis

The audiotaped interview notes were content-analysed in terms of: 1) experts’ own ideas on successful kaizen processes; 2) their reactions to the four graph examples, including their average ratings of the process; and 3) their overall ratings of the quality of the process in all 21 meetings. Stepwise regression analysis was conducted, with the experts’ average IPQ rating as the dependent variable and each of the possible quantitative indicators (Table 1) as the independent variable.

Results

Below we first report the experts’ verbal reactions to the graphs, after which we report our scrutiny of Table 1’s quantitative indicators.

Expert’s evaluations of kaizen IPQ

The experts defined kaizen as a phased team process to attain and implement a solution for a persistent problem. They stressed the quality of the process dialogue relies on very strict adherence to the six prescribed phases although, to share and explore perspectives, some jumping between phases is allowed. We derived a shared set of success criteria for kaizen’s internal process quality from their comments (Table 3). The table shows that, apart from the six phases, or “stairs” as the experts referred to them, some flexibility (e.g., jumping between phases) in a kaizen internal process is allowed.

Table 3 – Experts’ Views on the Role of Kaizen Process and Kaizen Phases

| Derived success criteria | Illustrative quote |
|---|---|
| 1. All six phases of the kaizen process must be recognizable in the graph and in the right order | “I am looking for some kind of stairs.” (9) “To recognize the phases is important to be able to jump effectively.” (4) |
| 2. As the team must agree consensually to a phase result, before moving to the next phase, the team | “Iterations can occur during the phases; that is no problem- the interesting thing is what they do with them.” (3) |

| | |
|--|---|
| members may need to make iterations from one phase to another | “You need the opportunity to enrich your discussions.” (6) |
| 3. A relevant remark is one that is discussed in the relevant phase | “I can see remarks in all the phases as well as a lot of jumping between all phases. This might make it difficult to follow, which reduces effectiveness.” (9) |
| 4. If not enough attention is given to a certain phase, the result of that phase might lack quality, which may lead to lower process quality in the next phase | “If you have limited problem definition, and you have only limited root cause analysis, you might only expect limited ideas for solutions.” (10) “Find the appropriate detail, measure and visualise the outcome (esp. value stream mapping).” (2) |
| 5. Check at the end of each phase if you are still working on the right problem (i.e., jump back to problem definition). It might help in focusing on the real problem | “The ideal situation is following the phases, but you should always be aware of the reason why you are doing kaizen.” (1) “It is a strength to jump back at the end of each phase in order to recalibrate.” (7) |
| 6. It is important to understand the ‘why’ for the instrument and the ‘why’ for each phase | “Be pragmatic, do not become a tool head.” (4) |
| 7. Based on the situation, one could decide to jump to a phase, and then go back again, as long as the phase results are defined in the right order | “I am missing content; the jump can be interpreted as positive as well as negative.” (5) “Sometimes the team needs some energy; the best thing to do then is to let them brainstorm.” (6) |
| 8. The process of kaizen is about learning | “The worst thing that might happen to the people is that they do not succeed and that they have not learnt.” (8) |

Note: The numbers in the second column refer to the different anonymised experts.

The experts were quite unanimous in their assessments of the IPQ from the four graphs (see Table 4, on page 7). For instance, all of them thought the second graph was chaotic, whereas the third graph was structured with a recognizable phased approach, thus positive process aspects. The average expert ratings of those example videos were also very consensual.

Comparisons of the experts’ perceived IPQ and quantitative indicators

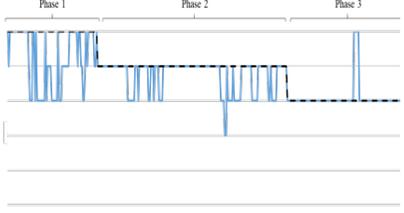
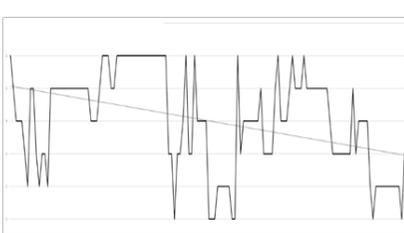
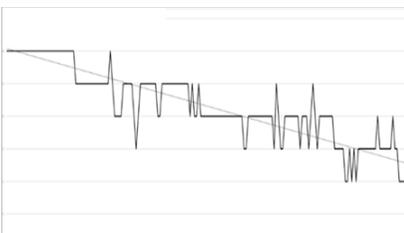
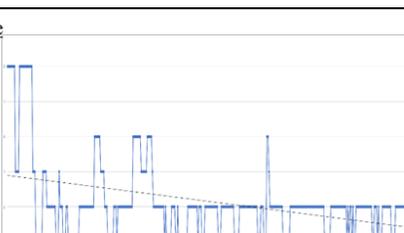
Both the calculated indicators and the experts’ IPQ ratings are reported in Table 5 (on page 8). We calculated the correlations between the average expert rating of the perceived IPQ and the eight indicators (Table 6, on page 8). Significant correlations ($p < 0.05$) appeared between the experts’ perceptions and the five IPQ indicators, especially the indicators ‘total squared jump value > 1’ and ‘total squared jump value’ (both: $r = .62$; $p < .01$). Three ratio indicators correlated marginally (Table 7, on page 8); indicators 4, 5 and 8), those taking the number of remarks into account.

Stepwise regression analysis pointed to one predictor, namely the ‘total squared jump value of jumps’, which explained 34.9% of the variance of the average expert ratings ($F(1, 20) = 11.74$, $p = 0.003$). The beta value of -0.62 indicates that when the squared jump-value has a higher outcome, the experts’ IPQ rating is lower. Hypothesis 7 is thus supported, whilst the others are not.

Discussion

While kaizen event effectiveness (Farris *et al.*, 2009) and team problem solving research (McFadzean, 2002) emphasise the need for an effective internal process, most empirical studies are based on subjective self-reports. Despite team process surveys being constantly optimised, there is a call for objective real-life observation data-gathering methods (Mathieu *et al.*, 2019). So far, there is a lack of a more objective way of studying kaizen internal process quality (IPQ). We developed a less subjective measure: after coding the remarks made in actual kaizen meetings, we rated their invoked phases and

Table 4 – Experts’ Reactions to the Four Example Graphs, Based on the Think Aloud Method

| Example graphs | Expert Quotes | Experts’ average ratings | | |
|---|--|--------------------------|---------------------|-------------------|
| | | Overall process | Structured approach | Expected solution |
| <p>KE phase</p>  | <p>“They took their time to get to the PD, spent time on root causes. That is good.” (2) “They start with PD, and then jump about, which is good although I would have expected them to take more time. It seems a bit restless.” (3) “I think they are doing quite well. You see them jumping but I think this is their way of exploring the problem.” (7) “It seems they get a bit stuck in the PD phase. They’re doing quite well on the phases” (9) “In the first phase, they mixed PD and GI up, a bit like playing ping pong, which might be a way of exploring the problem.” (10)</p> | 5.22 | 4.75 | 5.22 |
| <p>KE phase</p>  | <p>“They discuss more phases, but over time it becomes chaotic, looks like lack of consensus and decision making, so probably a confusing meeting.” (1) “Very interesting, as if they are going nowhere. I don’t expect good outcomes.” (3) “Seems very chaotic, goes everywhere, and they discuss the PD rather late” (5) “They know the solution before the problem; a complex team, seems they have some collaboration issues, and no effective goal.” (7) “It seems they have a solution and now they are looking for a problem, you can call it iterative, but I think it is just going everywhere.” (10)</p> | 2.78 | 2.25 | 2.67 |
| <p>KE phase</p>  | <p>“They finish something before they continue, PD is fast, RA takes longer, that’s what you want to see, the problem seems clear.” (1) “They don’t go back to PD: it seems there is consensus on that, that is positive. Looks structured.” (5) “They really start with the PD discussion, rather step by step, looks good.” (6) “Rather structured, they seem to recap before moving to the next phase, that is good.” (7) “Seems structured, not wobbly. If they continue this way, I expect they will learn how to attain a working countermeasure.” (8)</p> | 6.00 | 5.63 | 6.00 |
| <p>KE phase</p>  | <p>“They start with experiments and this will lead, at some point, to a working solution, but it is not a kaizen process.” (2) “It seems like they are firefighting, this is not about doing kaizen.” (3) “This looks like non-structured problem solving; will they be lucky and find a solution?” (4) “Oops, interesting team dynamics but not kaizen.” (6) “Low expectation; they jump to solutions. It looks like the Kata approach. I really can’t see the root cause analysis and the ‘stairs’.” (9)</p> | 2.22 | 1.85 | 1.89 |

Note. The abbreviations in the left column stand for: KE=Kaizen Event; PD=Problem definition; RA=root cause analysis; GI=idea generation; PI=plan implementation; I=implement; CS=check and sustain. The numbers in the second column refer to the experts. The experts rated the example graphs on a 7-point Likert scale, 1=very bad, 7=very good.

Table 5 – Video-based Ratings, Including Quantitative Indicators and Experts' Perceptions

| Video | Total no. of remarks | Video-based quantitative indicators | | | | | | | | Experts' ratings of perceived IPQ | |
|-------|----------------------|-------------------------------------|----------------------------|------------------------------|------------------------|-------------------------------|---------------------------|------------------------------|---|-----------------------------------|------|
| | | No. of jumps >1 | Total jump value jumps > 1 | Total squared jump value > 1 | Ratio no. of jumps > 1 | Ratio squared value jumps > 1 | Total jump value of jumps | Total squared value of jumps | Ratio total squared jump value of jumps | Mean | SD |
| 1 | 192 | 7 | 15 | 33 | 0.04 | 0.17 | 68 | 86 | 0.45 | 4.56 | 0.96 |
| 2 | 284 | 29 | 64 | 146 | 0.01 | 0.51 | 103 | 185 | 0.65 | 3.89 | 0.87 |
| 3 | 160 | 10 | 20 | 40 | 0.06 | 0.25 | 60 | 80 | 0.50 | 7.33 | 1.05 |
| 4 | 224 | 0 | 0 | 0 | 0.00 | 0.00 | 9 | 9 | 0.04 | 6.83 | 0.67 |
| 5 | 399 | 13 | 27 | 57 | 0.03 | 0.14 | 80 | 110 | 0.28 | 5.61 | 1.20 |
| 6 | 312 | 3 | 6 | 12 | 0.01 | 0.04 | 35 | 41 | 0.13 | 6.39 | 1.56 |
| 7 | 142 | 20 | 50 | 136 | 0.14 | 0.96 | 81 | 167 | 1.18 | 4.89 | 1.10 |
| 8 | 196 | 1 | 2 | 4 | 0.01 | 0.02 | 46 | 44 | 0.22 | 7.67 | 1.05 |
| 9 | 225 | 12 | 35 | 123 | 0.05 | 0.55 | 64 | 152 | 0.68 | 4.22 | 0.79 |
| 10 | 138 | 0 | 0 | 0 | 0.00 | 0.00 | 40 | 40 | 0.29 | 7.28 | 0.79 |
| 11 | 78 | 7 | 16 | 38 | 0.09 | 0.49 | 44 | 66 | 0.85 | 6.39 | 1.20 |
| 12 | 61 | 3 | 6 | 12 | 0.05 | 0.20 | 16 | 22 | 0.36 | 7.78 | 1.00 |
| 13 | 205 | 1 | 2 | 4 | 0.00 | 0.02 | 22 | 24 | 0.12 | 4.67 | 0.82 |
| 14 | 343 | 1 | 20 | 6 | 0.00 | 0.02 | 14 | 30 | 0.09 | 7.50 | 1.00 |
| 15 | 278 | 10 | 20 | 40 | 0.04 | 0.14 | 57 | 77 | 0.28 | 5.00 | 1.33 |
| 16 | 262 | 4 | 9 | 21 | 0.02 | 0.08 | 65 | 77 | 0.29 | 7.78 | 1.13 |
| 17 | 500 | 3 | 6 | 12 | 0.01 | 0.02 | 47 | 53 | 0.11 | 5.72 | 1.13 |
| 18 | 427 | 9 | 22 | 56 | 0.02 | 0.08 | 62 | 96 | 0.22 | 3.44 | 1.50 |
| 19 | 449 | 9 | 18 | 36 | 0.02 | 0.08 | 47 | 65 | 0.14 | 8.00 | 1.08 |
| 20 | 381 | 11 | 22 | 44 | 0.03 | 0.12 | 64 | 86 | 0.23 | 7.39 | 1.15 |
| 21 | 186 | 2 | 4 | 8 | 0.01 | 0.04 | 6 | 10 | 0.05 | 7.61 | 1.33 |

Note. Experts marked each video representation on a 1 (very bad) to 10 (very good) scale.

Table 6 – Paired Samples Correlation

| Video based quantitative indicators | Average expert ratings of perceived IPQ |
|---|---|
| 1. Number of jumps >1 | -0.54* |
| 2. Total jump value jumps > 1 | -0.54* |
| 3. Total squared jump value > 1 | -0.62** |
| 4. Ratio number of jumps > 1 | -0.44* |
| 5. Ratio Squared value jumps > 1 | -0.38† |
| 6. Total jump value of jumps from ideal process | -0.52* |
| 7. Total squared value of jumps from ideal process | -0.62** |
| 8. Ratio total squared jump value of all jumps | -0.37† |

† p < .10; * p < .05; ** p < .01

projected the data on a timeline, showing the deviations from an ideal structured problem-solving process. We presented 21 sets of the team-member remarks from real kaizen meetings to ten kaizen experts to obtain a measure of fit between their perceived IPQ and the calculated indicators. The study points to the total squared jump value of jumps from the ideal process of a minutely video-coded kaizen meeting as an indicator of a kaizen meeting's IPQ. In other words: each jump to another kaizen phase negatively influences the perceived IPQ and since we use the squared jump value, large jumps (i.e., skipping one or more phases) are considered to have a worse influence on IPQ.

Knowing that effective engagement in kaizen is essential for successful lean management (Bessant *et al.*, 2001), it is crucial to conduct an effective internal kaizen process (Farris *et al.*, 2009). Although kaizen is often regarded as a structured phased approach, it is rarely studied as such. Hence our study, which was to gain a better

understanding of the quality of the team meeting processes (Kozlowski, 2015). We contribute an innovative way to represent the phases in a kaizen event and use mathematical functions to spot ideal process deviations. Our quantitative measure adds to group problem-solving theory; it could be used by various future researchers to optimize the kaizen outcomes.

Adopting lean management also requires embracing learning at all organizational levels (Powell and Coughlan, in press). Improving a kaizen team's problem solving skills requires team level development and learning (Knapp, 2010). Team skills enhancement needs effective feedback. Abstract visualizations of a prior process could be helpful (Hassell and Cotton, 2017), especially to train facilitators and team members to understand the kaizen process better. This outcome supports our assumption that the graphs may be a useful instrument to judge, evaluate and learn from a team's internal process quality. A team can acquire dynamic problem-solving capabilities from such graphical feedback and our measure of what constitutes a 'good' (i.e., high-quality) kaizen process.

Limitations and suggestions for future research

Limitations of this study mainly concern the relatively small number of video-taped kaizen meetings. Access to more graphically depicted data on structured or phased problem solving may result in an even more valid measure. Moreover, asking multiple raters assign remarks to the six phases, leading to the graphs, could reduce potential single-observer effects. Including the kaizen participants' self-ratings of the IPQ could also improve it further. Plus, we only studied each first and sometimes a second meeting of a kaizen event. However, all ten involved kaizen experts had many years of experience in a variety of industrial sectors, but they could have been positively biased vis-à-vis the ideal kaizen phases. Hence, it would be interesting if non-kaizen problem-solving experts rated the graphically displayed processes of problem solving. Despite these imperfections, we are confident that data saturation occurred for the purpose of building the measure.

As team problem-solving skills do not come naturally to all members, teams that start adopting kaizen have to learn how to perform this process. All the teams that participated in our study also received the graphs as feedback and they lauded the insights gained upon discussing them. Hence, future longitudinal intervention studies of this graphical form of team feedback is called for.

Regarding kaizen as a structured phased approach, distinguishing the contributions per phase, visualising them in a graph and calculating the process quality indicators as a more objective measure of kaizen event IPQ, certainly creates new questions. Future research might focus on a better understanding of the contribution of individuals in a team to each kaizen phase, by exploring personal preferences, skills and optimal team composition (Franken et al., 2019; Kozlowski, 2015). The herein presented video-based, quantitative measure of a kaizen event's internal process quality may function as a springboard for more impactful learning in Operations Management theory and practice.

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