

# ENABLING OBJECTS FOR PARTICIPATORY DESIGN OF SOCIO-TECHNICAL SYSTEMS

**Ole Broberg**

Technical University of Denmark, DTU Management Engineering, Denmark

## **ABSTRACT**

The aim of this paper is to identify and explore the role of objects in participatory ergonomics design processes. The question in focus is: What characterizes objects in PE processes? First the concept of boundary objects is introduced as a starting point for investigating the role of objects. Second, findings of a search to identify objects in PE processes are reported. Third, objects fulfilling the requirements for boundary objects are placed in one of five categories. Fourth, empirical findings from two PE case studies in which objects played an important role are presented. Finally, based on a grounded theory approach, a characterization of objects in PE design processes is developed and a framework for how the use of objects in PE processes could be conceptualized is proposed. In conclusion, the concept of objects in PE processes is contextual, and the ergonomist or other design actor needs to actively consider their selection and the stage at which they are to be used.

*Keywords: Participatory design, socio-technical systems, objects*

## 1 INTRODUCTION

In recent years much attention have been given to the role of objects in engineering design as well as other design processes [1][2][3][4][5]. Objects may be defined as all sorts of physical and electronic artefacts, including sketches, technical drawings, mock-ups, and computer models [5]. Objects are seen as having an important role in facilitating multi-disciplinary design processes, and improving design communication in general.

In a broader view of engineering design, Boujut & Blanco [6] pay particular attention to the interfaces between the actors involved in collaborative design processes. They observe the features of objects, which they, in line with Vinck et al. [7], term ‘intermediary objects’, such as mediation, transformation or translation, and representation. Intermediary objects are representations of a final object. “They are supposed to be objects that can be communicated and exchanged between design partners. Their goal is to improve exchanges, enable viewpoints from various trades to be expressed and compromises to be achieved” [7]. In this understanding, objects have an active role in the design process. A prototype is not only a new shaping of what is represented in the drawing; it is a new version of the final product.

When introduced into the design process, intermediary objects are meant to communicate the intention of the author. The user of the CAD drawings is not supposed to interpret or transform the designer’s intentions, only to comply with them. The object is regarded as “closed”. On the other hand, if the object can be understood and modified by the various design partners, it is considered to be “open”. Users are not completely trapped by the object but have some degree of freedom in terms of use [7], and it gives access to the various participants in a collaborative design process. The actors can transform the objects into shared representations.

Much discussion on objects has focused on product design. In this paper we will turn to the situation of socio-technical system (STS) design. A STS may be a new or redesigned manufacturing facility, a hospital, or an administrative facility. A conceptual framework of STS may include four dimensions: Spatial arrangements, organization, technology, and finance [8]. STS design may often be a multi-disciplinary and distributed design process involving many actors. Some approaches are aiming at involving the end users of the socio-technical system in the design process. Within the field of ergonomics such an approach is termed participatory ergonomics design [9]. Ergonomics is aimed at the joint optimization of human well-being and overall system performance (IEA). Participatory ergonomics (PE) design is a pro-active approach directed towards the STS design process. Objects are

used in PE processes, and the study of their role may contribute to the overall body of knowledge on objects in design processes.

Participatory ergonomics in relation to STS design is faced by the question: How can workers and other workplace end-users participate in setting up measures for ergonomics, when the new workplace does not exist? This question is about representations of workplaces and work processes in design processes. If the ergonomist or another design actor has the role of guiding the PE process, he also has to consider what kinds of representations are useful in the design process. Studies of PE processes indicate that quite a number of different kinds of objects are used to represent features of the non-existing workplace and work process in design processes.

The representations constitute means of communication and are enablers of participatory design processes. For an ergonomist guiding a PE process, the involvement of objects should make it easier for the workers or workplace users to participate in the design process. This raises the question of whether some objects are better than others for doing this job. The aim of this paper is to identify and explore the role of objects in PE processes. The question in focus is: What characterizes objects in PE processes?

In the following, we first introduce the concept of boundary objects as a starting point for investigating the role of objects. Second, we report the findings of a search to identify objects in PE processes. Third, objects fulfilling the requirements for boundary objects are placed in one of five categories. Fourth, we present our own empirical findings from two PE case studies in which objects played an important role. Finally, based on a grounded theory approach, we develop a characterization of objects in PE design processes and propose a framework for how the use of objects in PE processes could be conceptualized. We argue that the concept of objects in PE processes is contextual, and that the ergonomist needs to actively consider their selection and the stage at which they are to be used.

## 2 THE CONCEPT OF BOUNDARY OBJECTS

The concept of boundary objects was introduced by Star & Griesemer [10]:

*Boundary objects are objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. They may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable means of translation. The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds.* (p. 393)

Carlile [4][11] analyzed the concept in studies of product development, and for him it describes objects that are shared and shareable across different problem-solving contexts. In line with Star & Griesemer but without using the exact same terms, he operates with three categories of boundary objects in the product development setting: first, *repositories*, i.e. cost databases, CAD/CAM databases, and parts libraries; second, *standardized forms and methods*, i.e. standards for reporting findings, problem-solving methods, or engineering change forms; third, *objects, models, and maps*, i.e. sketches, assembly drawings, parts, prototype assemblies, mock-ups, computer simulation, Gantt charts, process maps. Carlile [4] identifies three characteristics of a tool, method, or object that makes it useful in joint problem solving at a given knowledge boundary. A boundary object: 1) establishes a shared syntax or language that individuals can use to represent their knowledge; 2) provides a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary; and 3) facilitates a process where individuals can jointly transform their knowledge. Carlile [11] points out that boundary objects with different capacities are required, depending on the type of boundary faced.

In another field of research, Wenger [12] introduces the concept of boundary objects in social learning theory. He also focuses on boundaries and boundary processes. Boundaries connect different communities of practice and they offer learning opportunities. Boundary objects can be intentionally promoted to help bridging between communities and facilitate learning. In the words of Wenger: "Some objects find their value, not just as artifacts of one practice, but mostly to the extent that they support connections between different practices". Wenger suggests three different forms of boundary objects: 1) Artifacts, 2) discourses, and 3) processes. Artifacts correspond to Carlile's second and third categories. Discourses may be the existence of a common language that allows people to communicate

and negotiate meanings across boundaries. Processes include explicit routines and procedures in an organization.

While boundary objects may be considered part of the daily work in engineering design and product development, it is something new to bring this concept to the field of participatory ergonomics in relation to designing and planning new workplaces. Participatory processes in this area are often a series of discrete events with the aim of influencing the overall design outcome from an ergonomic point of view.

Working with boundary objects is not only about representing and transforming knowledge but also about facilitating collaborative design across *work practices* [13][14] – collaboration and coordination, not between engineers with different specializations but between workers, management, designers, and ergonomists with very different work practices and organizational positions. This is the challenge that led us to look for objects in PE processes that might qualify as boundary objects.

### 3 OBJECTS IN PARTICIPATORY ERGONOMICS PROCESSES

Table 1 summarizes our findings across a wide range of PE studies in the literature.

*Table 1. Categorization of boundary objects in PE studies*

Object type	Recorded in PE process
Repositories	None
Standardized forms and methods	Documents - Ergonomic “Blueprint” - Questionnaires - Injury reports - Lists of results and problems - Inventory - Layout diagram - Handmade sketches - Drawings - Diagrams - Tables - Meeting reports - Pareto diagram - Relations diagram - Tree diagram Breakthrough Thinking Usability tests Focus group interviews
Objects, models, and maps	Prototypes Test of workstations and equipment Slideshow with workplace pictures CAD Computer visualization - 2 D - 3 D - Animation - Mannequin - Virtual environment Scale or full-size mock-ups Production games Fishbone chart Ergonomics bulletin board
Discourses	Questioning situation Typical Action Situation Auto-confrontation Video recordings of work Dialogue model
Processes	Prototyping Test of new ways of working Visiting other departments or workplaces

We recorded every object stated in a paper regardless of its importance in the study reported. We then sorted the objects into the categories of Carlile [4] and Wenger [12].

We distinguish between prototypes and prototyping. Prototypes are physical or digital representations of a future artifact. Prototyping refers to the mutual learning *process* that takes place in a collaborative design setting. During the process, a prototype may be constructed and manipulated.

Table 1 presents an overview of objects that in one way or another have been involved in PE processes. The point is that many objects appear in PE processes, but their role, way of functioning and impact are very rarely discussed in the studies. Furthermore, it is not evident whether there have been any considerations about choosing among more possible objects. This may affect their quality as boundary objects in PE processes. Only in studies focusing on computer visualizations do there seem to be deliberate discussions of their role and quality as communication tools in the PE design process [9][15].

The next section reports empirical findings from two participatory ergonomics design studies in which objects played an important role.

## 4 OBJECTS IN DESIGN PROCESS INTERVENTIONS

The two cases are from a research program that developed and tested a framework for participatory design of workplaces during the period 2005-2008. The aim was to develop methods and tools to be applied by ergonomists and other workplace professionals to stage direct participation in design and planning of new installations and production systems [16][17][18]. The authors were part of this research program. In this retrospective analysis, we present a number of objects taking part in the intervention and the context in which the objects were used.

The research program was based on intervention studies in two organizations: an industrial manufacturer and a public administration office. The industrial manufacturer was to implement a new production technology. Engineering designers, workers, management, and ergonomists were involved. In the public administration office, three departments were being merged, moving from cell offices into an open-plan office, and implementing new ways of working. Architects, workers, management, human relations people and ergonomists were involved.

The interventions were aimed at facilitating a collaborative design process for the future work and workplace. Special emphasis was placed on developing and testing methods that would make it easy for the workers to articulate their concerns and wishes and to participate in design activities. The format for the interventions was a workshop series in which different interactive methods and tools were applied: workbooks, layout design game, use scenarios, future workplace assessment, photo safari, and the dream office. The researchers, together with ergonomists and other workplace professionals from the two organizations, took on the role of facilitators and workshop leaders. Other researchers in the team evaluated the process of intervention and the outcomes of the workshops. The data for the cases were collected over a 12-month period, and included interviews and observations.

We present first a brief overview of the context in which objects were used. Then, we present the objects in detail.

### 4.1 The intervention context

In the industrial manufacturer company, we accomplished two workshop series, each consisting of two workshops. The first series focused on the layout of the production facility in which the new technology was to be installed. The main object was a layout design game. As a warm-up, the workers first did a workbook session. The first workshop series was held in a meeting room in the company. The second series was based on the layout resulting from the first series and focused on work processes and ergonomics that would be used with the new technology operating in the future layout. The main objects were a 1:20 scale model and floor markings in the actual production hall. Both workshops in this second series were held in the production hall where the new technology would be installed.

In the public administration office, a similar workshop series structure was used. Here, the focus is on only two objects: a photo safari and sketching the dream office.

All participants considered both interventions highly successful. The workshops in the industrial manufacturer case resulted in a new design of the layout and a detailed ergonomics specification list that was agreed to by all involved actors. The public office case resulted in workplace experiments

that were implemented in the existing office facilities, as well as a detailed proposal for the layout of the new open space office. The evaluation “highly successful” is based on interviews with participants after the workshops.

The production manager from the industrial manufacturer case stated that he was quite sure he had saved a lot of money by redesigning the layout and setting up specific ergonomic requirements. He was also quite satisfied with the methods used to involve the workers in the design process, hereby promoting ownership to the solutions. The workers stated that they really felt they contributed to the design process and that the engineers were listening to them. They found the workshop to be successful because they had a format that allowed them to act as co-designers. The design engineers, a little bit reluctant in the beginning, stated that this was a quite new experience that showed how much the workers could contribute to the design process.

In the public administration office, the head of department stated that he made a good investment by letting all the personnel participate in the workshop activities. Contrary to other departments in the administration office, he was sure that his department was very well prepared for the move to the open space office and starting new ways of working. He was glad that he could specify for the architects his personnel’s wishes for the design of their new open space office. The manager of a new-way-of-working project as well as the shop steward and several workers also stated that they found the intervention successful. Another indication was the fact that the workshops resulted in new experiments of layout and collaboration in the existing office.

## 4.2 Objects in the collaborative design process

In this section, we briefly present the objects and how they were used in the workshops.

Inspired by Horgen et al. [8], we used *workbooks* with a selection of pictures from the current workplace, which workers could comment on, using colored pens (Fig. 1). A three-color code was used to indicate, for example, good solution, problematic solution, and problem to be solved. The problems and solutions comprised ergonomic topics as well as production optimization topics. Workers presented their workbooks to the participants at the first workshop; they included design engineers, managers, and ergonomists.

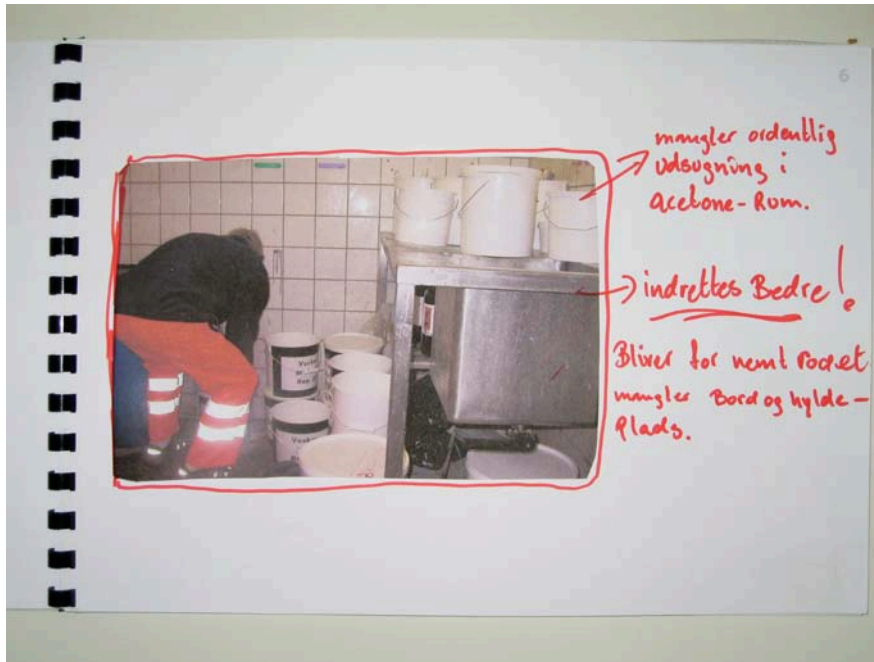


Figure 1. A page in the workbook filled in with operator’s comments

In the *layout design game*, a game board with a blueprint of the new facility is in the middle of the room at a workshop meeting. Moveable bricks in different colors represent machines, equipment, and installations. Each participant in turn manipulates the bricks on the game board and briefly explains

the idea (Fig. 2). The game explores different layout possibilities through “what if ...” experiments at the game board, and the impact of each on ergonomics and production issues.



*Figure 2. The layout design game*

*Use scenarios* were applied in two versions. In the first, the work processes and the spatial workplace were simulated with the help of a 1:20 scale model of the new facility, with moveable machine models and LEGO figures. We also used a kind of mock-up based on floor markings in the actual production hall where new machines were to be installed (Fig. 3).



*Figure 3. The use scenario playing out in the production hall*

The floor markings indicated machines, walls and doors. Different production episodes were played out, as if the participants were actually working with the new technology in the new facility. All participants were active in reflecting upon what worked and what should be redesigned. In the second

version, the same use scenario setup was applied for a future workplace assessment, where the ergonomist went on a virtual walk-through guided by the operators of the projected new facility. This event identified ergonomic and safety and health factors that had not been recognized previously. In a *photo safari*, four teams of workers from the public administration office, armed with a digital camera, went to visit four organizations with open-space offices. They took pictures and conducted short dialogues with people. After returning, each team presented a selection of photos at a workshop and explained what they liked and disliked, and what the impact could be for design of their future workplace. In the *dream office* session, teams of workers sketched their dream office as a poster, sometimes using allegories to explain the idea. The sketches included ideas of physical layout as well as work organization issues. The sketches were presented to the other workshop participants and discussed.

## 5 CHARACTERISTICS OF THE BOUNDARY OBJECTS

The five objects presented in the previous section were tested as tools in a kind of participatory design process, which in the future could be guided by an ergonomist. The objects used in the two cases functioned as boundary objects, and according to participant interviews, they were considered by all parties to be doing a good job. In order to find out why they are doing a good job, we will characterize these objects and their context of use.

The five objects and their context of use were analyzed with inspiration from a grounded theory approach [19]. The data material used for coding were four-fold: 1) Field notes from observations of the objects “in action” in workshops; 2) the researchers’ subsequently written description of the setting and the process that took place in the workshops; 3) video recordings of the workshops; and 4) transcripts of interviews with participants after the workshops. This material was selectively coded using the guiding questions: What characterizes the objects and their use context? What are the objects able to do?

From this analysis, the following eight characteristics emerged.

1. The objects do not come ready made. They need to be created through the actions of the participants. They are *objects-in-the-making*. The workbook has no meaning before the workers have drawn and commented on the pictures. The blank blueprint layout cannot be understood before the participants have furnished it with bricks representing machines, walls, equipment and the like in a specific configuration. The use scenarios *are* inherently actions by the participants. The photo safari forces the participants to think about which pictures from an unknown workplace are interesting and why. A blank piece of paper has no meaning before a team of workers has drawn their dream office.

If we compare the objects in this analysis to some of the objects listed in Table 1, the latter seem to be more like *facts* or at least ready-made objects. This applies for example to injury reports, diagrams, tables, drawings, meeting reports, and inventories. These objects may of course be discussed, but they do not in themselves invite to any sort of design action.

2. The objects in the two cases have this capacity. They have *built-in affordances* to make a design develop or to articulate what is good and bad design. Affordances are the possibilities for action provided by the environment. The bricks in the layout design game are interaction instruments for the participants [20]. By manipulating the bricks they make a design action. When a participant places a brick, he is “forced” to explain why this is good design for him. If he moves a brick placed by another participant, he has to explain why it was bad design that has to be changed.

3. Some of the objects – the layout design game, the use scenarios, and the dream office – are *flexible and malleable* in a way that makes it possible to begin “rapid prototyping” with the new workplace. In the layout design game, it is very quickly possible to explore the question: “What if we place the machines in this way?” In the use scenario, it is possible to illustrate and reflect upon the question: “How about doing the work sequence in this way?” The capacity to test different configurations quickly contrasts with CAD drawings and computer simulations, which require time-consuming programming or other work with the software before an alternative can be presented. CAD technology and computer simulations of workplaces are developing quickly and can of course be used in PE processes. Using such objects, however, will set up another participatory process that is characterized by a ‘visualization delay’, when participants make a design move, and by the need for participation by CAD specialists [21].

4. The boundary objects require *rules and instructions* for their use. For example, the workbook: use the red pen for problems, the green one for good design; the layout design game: manipulate the bricks

after turn and give a short explanation when you move bricks; the use scenario: act out specific sequences of work in the new production system, so we can examine ergonomics in the control room, and take part in reflections; the photo safari: take pictures of things you like or dislike, of designs related to how citizens are met in the office etc.

5. A *facilitator* of the events selected the boundary objects, developed the rules and instructions, and guided the workshops in which the objects were used.

6. The boundary objects are used in discrete events (i.e. workshops), under the guidance of a facilitator who has developed the rules and instructions. This set up establishes a *temporary learning space* in the organization. The guidance and rules and instructions help this temporary space to some extent to dissolve the daily organizational structures, roles, and politics in which participants are embedded. This set up enables a collaborative design process. It promotes all participants into a “design mode”, rather than a “negotiating mode” based on daily conflicts of interests. The objects become boundary objects in a learning process between different communities of practice [12]. In both organizations, we were aware of minor conflicts and disagreements between management and workers and between different groups of workers. This awareness was based on interviews and our presence in the organization for observations or workshops. The evidence that the “design mode” was prevailing is based on the observation that these conflicts never became an issue during the workshops. There were some minor remarks but never in a way that derailed the collaborative design process.

7. The *location* of the boundary object needs attention. The layout design game was played out in the company’s meeting room in the administration building. This is a very familiar environment for design engineers and managers, but for the workers it was unfamiliar. In contrast, the use scenarios took place in the production hall. Here, the workers were playing at home and the design engineers away. The location issue leads to a general consideration about whether the use of boundary objects can be embedded in the workplace and in work practices that are to be redesigned.

8. The boundary objects themselves become an output from participatory events. They articulate a piece of design that has been *materialized* and can then be *circulated* in the organization, also in the ongoing design process. When all participants agree on the new layout or when a compromise has been reached, it can be seen directly on the game board; the bricks on the game board are frozen in a specific configuration. Such materialized outcomes from participatory events may better support the results being taken into the further design process. They may even have a political character in the ongoing design process. Workers can physically point to the ‘frozen’ boundary object and present it to other actors in the organization [2].

The findings of this analysis are summarized in Table 2.

Table 2. Conceptualization of objects in participatory ergonomics design processes

Attribute	Characteristics
The boundary object	Object-in-the-making Built-in affordances Flexible and malleable
The context of use	Facilitator stages and guides Rules and instructions Temporary learning space Location of workshops
End product	Materialized outcome

## 6 CONCLUSION

Based on two intervention case studies, we have identified eight characteristics of boundary objects and their use. It is an important point that these characteristics go beyond the object itself towards the use context and the outcome of applying the objects in a PE design process. Thus, we have a tentative framework for boundary objects in a PE design process, as indicated in Table 2.



The selection of objects as boundary objects in PE processes is of great importance, since different objects enable workers' participation and collaborative design in different ways. The framework can serve better understanding of the role of boundary objects in PE processes and provide some criteria for practitioners and intervention researchers to guide the selection of objects to facilitate a PE process.

Ergonomists taking part in PE design processes have to make sure that all participants are able to contribute to the design process. When it comes to design of new workplaces and production systems, it may be difficult for the future workplace users to contribute, if the representations of the future design are solely in the language of engineers and architects. Boundary objects are needed that can create a common language, which allows all participants' knowledge and ideas to be represented. Focusing on PE design, it is also important to identify boundary objects that have the ability to act as design objects. They must be objects-in-the-making.

The notion of closed and open objects clearly touches on this. We argue that closed objects are primarily meant to *transfer* the intention of one designer to another. A CAD drawing is the specification for building a prototype. The drawing is not supposed to be interpreted by the prototype builder; it is supposed to be transferred accurately into a prototype. If a CAD drawing is used as an object in a PE design process, it would only invite the participants to *comment on* it. The engineer or architect can of course afterwards change it, but in the PE design event, it is only possible to comment on this object.

We argue that open objects, on the other hand, are not intended to transfer but to allow a *transformation* of the participants' different design ideas. The participants in a PE design process can *design with* such objects. The participants in a collaborative event can transform an open object into a shared representation of the future workplace or production system.

For an ergonomist with the role of facilitating a PE design process, the following guidance on using the framework may be useful:

1. Situational awareness is required when planning a PE design process. What is going to be designed in the technical or architectural design process? Who are the designers? What is open to design or redesign in the process? In what stage of the overall design process is the PE design events placed? What are the goals in setting up PE design events? Who should participate?

2. Organize the PE design approach in a number of interconnected workshops with participants from management, workers, and designers (engineers, architects and others). Be aware that PE design workshops are just one input to a more technically or architecturally oriented design process continuing for a longer period. Make sure that management is committed to integrate results from the workshops into the ongoing design process. Set up rules and instructions for the PE design workshops that promote setting the participants in "design mode" instead of "negotiating mode".

3. Boundary objects in PE design processes should be selected on the basis of the understanding that they also have to act as design objects enabling the participants to design-with and not just comment-on. Do not use objects that are only intended to transfer a design specification accurately - and which the participants are only asked to comment on.

The objects have to be flexible and malleable in the workshop situation. Even if a trained CAD programmer can change a 2 D drawing, this is not flexible. It does not invite (afford) design moves. The best-suited objects allow playing out "what if ..." experiments of the future design. In this way, different scenarios of the future workplace can be tested instantly in a PE workshop.

What originally is a closed object may be changed into a more open object. Using transparent paper makes it possible to design a new layout to superimpose on a CAD drawing of a production layout. Or the drawing can be translated into a rougher floor plan in which the equipment and walls are bricks that can be easily moved by the participants.

4. Design objects are manipulated during the workshops, generating a potential new design of the future workplace in a collaborative design process. It is recommended that at the end of PE workshops these design objects be in a tangible design format that can be circulated into the ongoing design process, as a starting point for a more technical architectural design process. Finally, it is very important that the participants in the PE process can subsequently see how their contribution is incorporated into the final solution. When workers are invited to join a PE process, they have legitimate expectations to be taken seriously.

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