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Procedia Manufacturing 31 (2019) 337–342

Procedia MANUFACTURING

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9th Conference on Learning Factories 2019

Learning factories as laboratories for socio-technical experiments

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Abstract

Production systems might be viewed as complex socio-technical systems. A central part of socio-technical systems theory, is that improvements demands joint optimization of both the technological and the social parts of the system. Current research on socio-technical systems are, however, mostly interpretivistic with focus on qualitative and descriptive studies of existing manufacturing systems. Learning factories are full scale manufacturing simulators where it could be possible to perform experimental studies on socio-technical systems. This paper discusses the methodological aspects of such experiments and relates the discussion to 15 years experiences from a hospital simulator.

Peer review under the responsibility of the scientific committee of the 9th Conference on Learning Factories.

Keywords: Learning factory; Socio-technocal experiments

1. Introduction

1.1. Learning Factories

Learning Factories are physical learning spaces where social, practical and theoretical skills can meet and evolve [1-18]. The term dates back to the nineties and was born from the need to have more practical education of engineers, copying the model of nurses and medical doctors' education using university hospitals. Practical training in real factories has some limitations though, experiments and trial-and-error are costly and therefore not allowed. Since then the concept has evolved to include high-fidelity factory simulators where experiments, research and education can be combined. Such a Learning Factory emulates a real factory, contains real live processes, products and people. Abele et al. [4] has been working on a learning factory morphology, and the focus is on practice-oriented

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2351-9789
Peer review under the responsibility of the scientific committee of the 9th Conference on Learning Factories.
10.1016/j.promfg.2019.03.053

learning processes, but the effects on learning outcome and best didactical approaches are not well mapped yet, although there has been increased focus on this lately [16-18]. Another debate is whether learning factories are focusing too much on efficiency, as in reducing production costs, rather than human needs and demands in the manufacturing systems [7]. Although Abele et al in [1] and [4] mentioned learning factories used for research, literature mainly discusses the learning and training aspects of learning factories. Using a learning factory for socio-technical manufacturing research with interaction between humans and technology are not extensively discussed in literature and this paper aims at establishing some theoretical ground for this.

1.2. Socio-technical systems

The concept of Socio-technical Systems challenges technology determinism and puts humans in the workplace in focus. Since manufacturing systems always will contain humans in some way, any such system will have the characteristics of socio-technical systems with relationships between machines, between people and between machines and people. This implies that holistic research on a manufacturing system needs to analyse both the technical and social system regarded as sub-systems to complete socio-technical manufacturing system [19]. It is in this respect that the socio-technical perspective is not only important while designing a technical system, but equally important in establishing a platform for the research on manufacturing systems.

When studying a socio-technical system, the "rules" of both natural- and social sciences needs to be applied, and the applied research paradigm; beliefs of what knowledge is and how knowledge is achieved. The researchers ontological, epistemological and methodological views are here important. The researcher ontological view will influence the epistemological view and affect the view on the social system. You can basically think of peeling of an onion. One peeler can do this with a preunderstanding that the solution can be found in the centre. Another peeler has a different view, each layer peeled gives new information about the problem. However, this peeler is not looking for (and this will not find) the "ultimate answer" hidden inside the onion. The layers are pieces of information about the phenomena that gives deeper insight to the study. In this analogy; looking for the "ultimate answer" could be classified as a positivistic view, and the effort of looking at phenomena from various angels is more of interpretive view. The simplified example illustrates that researcher from one or the other basic view is not looking for and will not reach the same conclusion. As consequence to the ontological and epistemological views, the researcher chooses a methodology based upon the assumptions that has been taken.

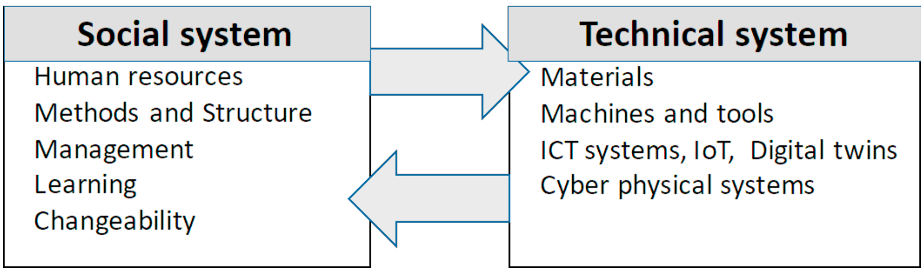

Fig. 1. Illustration of a socio-technical system.

Arbnor and Bjerke [20] has a simplified description of methodological views and grouping them into analytical-, systems- and actor view (se fig. 2). The analytical views reality as filled with facts independent of the perceptions of the researcher. Basis of knowledge is facts, and the research aim is to explain a reality as objective as possible. The systems view (holism and structuralism) also assumes a factive reality, existing of components mutual dependent. To study a single component alone will not work, only a holistic view can give an appropriate explanation. The actors view is that reality is socially constructed and knowledge is dependent on how individuals/actors create knowledge, perceive and understand reality. While the analytical researcher typically takes an objective, observers view, will the actor researcher strive to become a part of the process, and achieve insight through interacting. In an actors view is pure objectivity not possible since "reality" is created by humans.

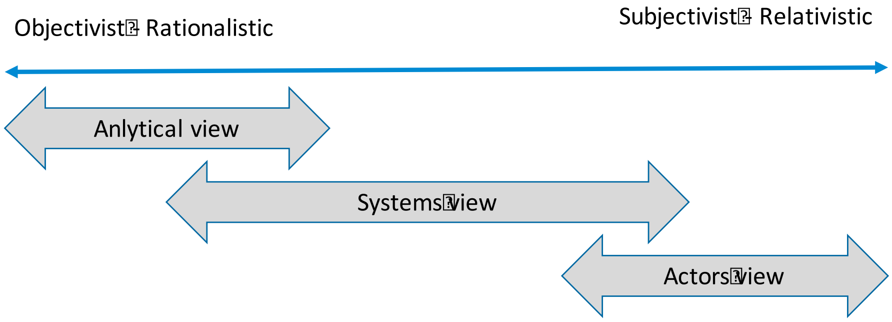

Fig. 2. Different methodological views [22].

1.3. Using Learning factories as laboratories for experiments to gain manufacturing systems knowledge

In social science, there has been a scepticism of using laboratory experiments away from "real life" practice. The well-known Hawthorn –studies [21] has been used as an example of the pitfalls of positivistic laboratory studies. The scepticism, is on how well experiments in some sort of laboratory, can be representative of the reality and the complexity of manufacturing systems where humans are involved. Spun out of the positivism dispute [25] and much later exemplified by Snow in his Reve speech at Cambridge University [26], a current view on social science needs to investigate social phenomena in practice in order to fully comprehend the complexity of reality. More importantly, it relates back to the Cartesian doubt and the more modern challenge of systematic doubt, where the existing known is challenged [27]. Initial thoughts went through a process of rethinking. Such a process enables new dimensions and understanding of the phenomena to emerge. A typical critique is that the social science researchers are collecting "snapshots" in time and space of the complex reality, coloured by the philosophical views of the researchers and the current state-of-mind of the informants and their manufacturing system. Following the reasoning, the "snapshots" need to be repeated at different times with different philosophical views and at different sites before deeper understanding and insight of a phenomenon can be reached. Furthermore, has some critiqued how suitable social science is to plan and shape future changes [28] with most focus on "as-is" descriptive research. On the other hand, has "what-if"/"to-be" typically been engineering work using simulation (digital) models, where social aspects of the systems is usually only weakly (if at all) regarded. A Learning Factory environment might be suitable for validation of a digital model through physical experiments, and the authors of this paper argue that using Learning Factories concepts as laboratories for experiments on manufacturing systems could contribute to fill this gap. Learning factories are fairly close to reality and can conduct "real life" simulations with human - technology interaction, possessing some level of complexity. In addition, can motion tracking, monitoring of hart beat etc. be possible in a learning factory. Therefore, research done in Learning Factories could contribute to valuable and science based insights and understanding on future and current manufacturing systems. The simulations and the attached studies must, however, take into considerations the before mentioned "rules" of social science research.

2. Experiences from NTNU Nursing school simulation center

NTNU has 15 years of experience with real life simulation from our nursing school simulation centre. A hospital "department" is built with 10 hospital beds with advanced artificial patients supplied by Laerdal Medical [29-31], and an external control centre where the "patients" symptoms and reactions to treatment are controlled. Everything is filmed and all relevant data are recorded. Furthermore, we have an ambulance simulator and pre-hospital simulation facilities including a car wreck for simulation of in-the-field first aid. In a simulation run there are three main roles; the researchers/teachers, the controllers and the simulants.

Fig. 3. NTNU Nursing school simulation center.

Simulants are usually students but could also be experienced nurses. The controller(s) controls the “patients” from the control room as well as supervising all data collection/measurements, videos and technical equipment. The researcher and/or teachers are in charge of design of simulation scenario, briefing and de-briefing the simulants as well as analysis of the results. In addition to a high-fidelity simulation infrastructure (in this case the “hospital room and pre-hospital simulation room) the following is of importance to get a realistic, high fidelity simulation with good research or learning outcomes;

1. Training of the everybody involved in the “art of simulation”
2. Briefing of the simulants/students before each run
3. Proper de-briefing after simulation runs

Experiences form the nursing school simulator shows that knowledge and experience in the “art of simulation” is important to get a successful simulation. Without this, the simulation can be unnatural. Before a simulation run, the simulants must get a good briefing about the simulation from the researcher/teachers, step by step. It is usually not a good idea to surprise the simulants because of the uncertainty and deviations it can create. In practice, nurses will have experience and know how to act on upcoming incidents. Unprepared, the simulation will be less realistic and it could mean a waste of time. The de-briefing is the most important part both for learning outcome and research results, giving the opportunity to critically reflect on their simulation. A special debrief tool-set is reported in [32] using set of questionnaires and debriefing scales; "*Educational Practices Questionnaire (Student Version)", "Student Satisfaction and Self-Confidence in Learning", "Simulation Design Scale (Student Version)" and "Debriefing Experience Scale*". These instruments are all developed in order to reinforce knowledge on effect of simulations as learning methods and is used in addition to interviews and group discussions.

3. Steps in the Learning Factory manufacturing systems research

The research would typically follow the following steps;

1. Define the social science philosophical viewpoint
2. Define research questions
3. Design simulation scenarios
4. Technical preparation of simulation run(s)
5. Pre-briefing of simulants
6. Simulation run(s)
7. Post-briefing of simulants
8. Results processing and analysis
9. Plan new experiments - restart at (2) or (3).

Step (1); as discussed in chapter 1.2 should social science research start with a definition of the philosophical viewpoint(s) of the actual study. To use a learning factory simulation for laboratory style research would need the same type of definition of a viewpoint. We claim that case studies at a real manufacturing plant or a simulation at a learning factory run would meet similar challenges regarding validity and possible generic/normative research. Step (2); The selected research questions reflect the defines philosophical viewpoint, and these are both decisive for step (3) design of the simulation scenarios. The design will have to decide on topics such as:

a. Simulation tasks and simulation narrative
b. Predetermined technological structure and boundaries
c. Selection of simulants – students/operators/engineers/managers …
d. Randomized and predetermined parameters
e. Simulation measurements parameters

Step (4) and (5) prepare the equipment and the simulants for step (6), the simulation run(s). Data collection from sensors, movement tracking, monitoring of physiological reactions, videos, etc. must be prepared. Step (6) is the simulations runs, and (7) the de-brief. As mentioned is the de-brief especially important, it is here the results are created. De-brief would be a mix interviews, questionnaires (see [32]) and group analysis of numerical values from sensors, tracking/monitoring data. The last step (8) would be a scientific processing of all the data and go back to the research questions; Could we reach more insight after these simulations? At last (9) use the knowledge gained to plan new experiments; More data? What needs to be changed in the next simulations etc. Assessment of the social system would be a mix of interviews of the simulants and discussions on (if available) logging of physiological reactions, movements traced etc.

4. Discussion

The validity of experiments in a simulator can always be questioned but as mentioned, we believe they will fill a void between digital twin / numerical models and case studies of existing manufacturing systems. To simulate a socio-technical system the experiments should resemble a mix of human-human, human-machine and machine-machine communication to perform a specific task. With additional monitoring and data collection normally not possible in a real manufacturing system, controlled and delimited experiments can be performed. However, it will always mean a simulation, with a deviation to practice. How people act in a real working situation with real customers, suppliers, manager etc. would most likely be different, but the question how close is the simulation? Somewhat dependent on the selection of simulants there are many challenges where a Learning Factory simulation would meet shortcomings. In practice will organization culture, tacit knowledge, external influence from management, suppliers, communities of Practice (CoP) [32-33] at the workplace play an important role, and this is difficult to simulate in a Learning Factory. However; if the physical simulation is paired with a digital twin, a digital and physical simulation of a specific scenario can fulfill each other, moreover can (as discussed above) a Learning Factory simulation act as another "onion peel" with a different angle to the research questions raised and as complementary to case studies, questionnaires and interviews in practice.

Acknowledgements

This paper was based on activities within SFI Manufacturing in Norway, and is partially funded by the Research Council of Norway under contract number 237900. The authors wish to thank the Research Council for funding and the companies participating in the discussions for this paper.

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