New Paradigms for Assessing Innovations in the Technology Sector

Nicolina MONTESANO MONTESSORI
Faculty of Education, Utrecht University of Applied Sciences
Utrecht, 3584 CH, Netherlands
and

Anoop MATHUR
Terrafore inc., 1420 Iowa Avenue
Riverside, California 92507, USA
and

Stephen BOWEN
PlastiComp, LLC, 110 Galewski Drive
Winona, MN 55987, USA
and

Raj MATHUR
PlastiComp, LLC, 110 Galewski Drive
Winona, MN 55987, USA

ABSTRACT

This paper presents the potential of complexity theory (CT) combined with Participative Action Research (PAR) as a paradigm in social sciences. When combined with advanced learning systems [1], or a canonical model representation of complex systems, this paradigm can become a powerful tool to research, monitor and further design non-linear forms or entities in technology and industry. The paper starts with a description of general features of action research. It then indicates how this was used in a research project in four schools in the Netherlands. The simultaneous cyclical process of reflection, shared meaning and decision making, experimentation and evaluation in combination with a flexible but thorough emergent design and the use of grounded theory allowed for a research which brought into being an improved climate in terms of social justice. In dialogue with two engineering agencies, it was decided that this approach combines well with complexity theory and the development of intelligent applications of products and business performance. We will demonstrate this presenting two different industrial case studies in the fields of plastic composites and alternate energy.

Keywords: Participative action research, complexity theory, emergent research design, non-hierarchical relations, value based pricing, solar energy, triple bottom line.

INTRODUCTION

This paper shows how non-hierarchical, horizontal approaches to innovation through action research empower classroom educators and technical organizations to cope with complex issues and to produce innovative technologies and business services. The general problem these organizations had to face was: How to deal in a pro active way with contemporary social, business and technological problems? What can modern science offer to resolve these problems? We have been looking for answers in the realms of participative action research (PAR) and complexity theory (CT). We experimented with elements of PAR and/or CT in three different case studies. In this paper, we present these case studies and we will draw conclusions as to the merits of both PAR and CT and the ways in which they can reinforce each other.

We introduce some of the main concepts before proceeding to the case studies.

Action research is an emergent enquiry process in which applied behavioral science knowledge is integrated with existing organizational knowledge and applied to solve real organizational problems. It is simultaneously concerned with bringing about change in organizations, in developing self-help competencies in organizations and adding to scientific knowledge. It is an evolving process that is undertaken in a spirit of collaboration and co-inquiry [2]. Salient features are a collective, horizontal, democratic partnership and research in action. It involves double-loop learning, which implies a systematic dialogue and questioning of existing norms and beliefs in order to find the answer to questions like, “are we doing the right things in the right way?”. In other words, it implies looking below the waterline in the realm of norms and beliefs, motivations, interests and personalities. The assumption is that if nothing changes below the waterline, real changes in the visible and measurable ways of behavior are impossible [3].

Furthermore, it includes innovative forms of dialogue [4]. Features of this model are the sharing –rather than combating- of each others points of view and formulating shared views on alternatives. It is said that in this stage a “flow” is likely to emerge and be identified as such. This kind of dialogue helps to overcome the dominance of vested interest and of dominant people. A new context may emerge, which allows for the formulation of new solutions not thought of in the old situation.

Complexity theory overcomes limitations found in structural functionalism, while taking into account the philosophies of science and social science of the last fifty years or so. Complexity theory is based on a new scientific ontology (views on how the world 'works') and it rejects the epistemology of traditional science based on a linear logic of causal explanation. Instead, it offers explanatory accounts based on limited and contextual knowledge, open and unpredictable systems, and complex, non-linear interactions between elements, that leads to emergent properties and self-organizing structures and processes. This non-linear analysis places emphasis on interaction and feedback loops. The influence between components in a system can go in several directions at different times, and feedback iterations can change the whole system over time [5].

An emergent research design implies the structure of the research to be done. It has defined the research strategy (in this case: action research), the participants, and timing. It is stable enough to guide an unknown process between participants and flexible enough to leave room for decisions taken along the road. Favorite research instruments might include narrative inquiry, focus groups, participative observation.

Grounded theory implies theory which is formed or adjusted based on the research process and the collection of data. The underlying assumptions of the theory are tested throughout the research process [6].

PRESENTATION OF THREE CASE STUDIES

We now present three case studies: one performed in four schools in the Netherlands and two industrial case studies in the USA. The Dutch case study included a full cycle of PAR in order to find out what the implications of inclusive education in the light of social justice are for behavior and communication in the classroom. The first industrial case study focuses on the successful integration of business urgencies with democratic participation in PlastiComp, a small to medium sized business for advanced engineering plastic composites in Winona (MN), USA. The second industrial case study took place at Terrafore, California, a business partnership exploring alternate energy, used PAR to facilitate a shift in cognitive maps of the organization and, in general, to arrive at a business model which goes beyond mere profit and loss, but includes a triple bottom line approach. Furthermore, this case study demonstrates how complexity theory is used in the design of intelligent, or rules-based or knowledge-based controllers. Complexity theory refocuses our attention on system analysis, which we feel is widely ignored since the demise of Parsonian structural functionalism of the 1970's.

Case Study 1: Participative Action Research in the Netherlands: Researching Social Justice

From September 2008- June 2010, research on social justice was performed in four primary schools in the Netherlands, in cooperation with researchers from the Utrecht University of Applied Sciences and in the context of the research group on Behaviour and Research in Educational Praxis [7]. The practical problem to be solved was to generate knowledge on the implications of inclusive education in the light of social justice for behavior and communication in the classroom. The project, furthermore, attempted to create an alternative to the official discourse which emphasized a deficit approach which needed to be resolved by material means, such as money and remedial teachers. We emphasized the enriching elements of diversity and ways in which non-mainstream children can contribute. Research questions included: Which ways of communication and behavior between teachers and pupils and amongst pupils helps to create a climate of social justice? What are the dilemmas and restrictions that are found in this process? What does this mean for the educational climate and procedures in the classroom? Practice-oriented research – action research among them – consists of three stages, namely Orientation, Execution and Conclusions. The orientation stage started with narrative enquiries during which teachers presented their points of view on social justice and inclusive education. Based on the analysis of these narratives, a model was selected to analyze social justice. Since no model was available within educational theory, we selected a model from social theory [8], which stated that each social event consists of six moments which play a role simultaneously. These include: language, power, material practices, institutional practices, social relations, norms and beliefs. To this we have added social identities, based on the narratives. This is a typical example of grounded theory. Subsequently we asked participants to choose specific topics or moments to research in their class rooms. A few teachers wanted to research in what ways they could enhance ways in which pupils can resolve their own conflicts or control their own conflictive behavior. This became the definition of social justice within this research group. As such, this moment represented an example of shared meaning making. Once this definition was created, participants started to observe critical moments in their day to day practice. These were moments in which the normal procedure was interrupted and in which teachers experienced a conflict with their own norms and beliefs. First, the model was open and teachers described these critical moments. We then created a more structured form in which the description of the situation, a reflection on the situation and their own feelings, as well as on potential alternatives and the consequences of each alternative for themselves, the child involved in the situation and the entire group went hand in hand. They then decided which alternative would have the best outcomes. Finally, they formulated ideas to experiment with in the innovation stage. They related these ideas to the seven moments, listed above, which gave them a detailed view on the relation of their actions with power, language, norms and beliefs, etc. The researchers from the University of Applied Science responded to these descriptions, so that the research instrument succeeded in combining insider- and outsiders perspectives [9]. In doing so, this particular research instrument simultaneously fulfilled multiple functions of data collection, reflection, data analysis, feed-back from pupils and the integration of insider and outsider perspectives. These were discussed during focus groups. This research procedure allowed teachers to look at their practice through different lenses. The response of the outsider perspective helped them to shift their focus on the group to a focus on individual pupils. Dilemmas shifted all the time. During the narrative enquiry a typical dilemma was, "Do I attend to this one difficult child, or do I direct my attention to the group?" When describing critical situations, a typical dilemma was: "Should I intervene or let go?" In the final stages, after the innovation stage, dilemmas would concern the very behavior of the teacher. For example, "If I let go of my power position and give more space to each child, then what is my position? How can I redistribute power in the classroom". The research indicated that a climate of social justice requires a rethinking of teacher pupil relations in terms of a redistribution of power. Teachers facilitate and support pupils to become more independent and more responsible of their own behavior. It also taught us that the moments in the model need to be equally divided: if one dimension (for instance: parents) acquire too much power, they form an obstacle for the spontaneity of the teachers in their communication with the pupils. It proved that children, indeed, are very capable of resolving their own problems or negotiating solutions with their class mates.

Innovative Results of the Research on Social Justice

In retrospect, within management studies, the procedure followed in this research, was considered an improvement on Kurt Lewin's model on change [10]. Lewin developed a three-stage model of unfreeze, change, freeze. Within management studies, it was recognized that during research on social justice, these steps were taken simultaneously. It was a close spiral of reflections, observation, experimentation [11]. The advantages of this research and other research along these lines, is that a non-hierarchical, horizontal research process arises, which facilitates a free process of meaning making, experimentation and discussion.

Case Study 2: PlastiComp, LLC, USA Advanced Engineering Materials for Energy Conservation

For PlastiComp, being a small-to-medium size business situated in Winona (MN), the problem was how to establish itself in the market among the many multinationals which operate in the field of innovative plastics. It used a statement made by the Founder and CEO to his management team in answer to solving technical and managerial problems, *"It all depends on everything."* to engage in a process of PAR. Research questions included: how can we identify markets on which we can operate? How can we develop a healthy pricing system? A horizontal, non hierarchical research group was formed consisting of the management, board of directors and the employees of PlastiComp in order to study these issues in agreement with the principles behind PAR. In terms of the marketing question, this approach led to significant new insights as the basis for their innovated policy. Global markets are generally influenced by multinational corporations and their heft in sales or production volumes. PlastiComp has shown that it can influence the market in subtle ways. It licenses its proprietary technology to multinationals, although these behemoths end up as competitors. What is lost is potential market share, which the company believes is an imaginary quantity, anyway. What is gained is renewed activity in the market due to the presence of these global companies as active players. In turn such renewed economic activity invariably demands an optimum mix of large and small companies serving customer needs. Hence, PlastiComp's business opportunities are enhanced. Needless to add, licensed-technologies also create a modest revenue stream in terms of royalties. Note that PlastiComp has to still compete in the commercial arena and the entire process is not creating wealth out of thin air, but most closely hewing to free market dynamics. More precisely, PlastiComp creates markets, rather than fighting for a share of existing markets. For example, a market- leading plastics company based in Germany expressed an interest in participating with PlastiComp in developing new compounds based on the proprietary know-how of each company. They noted that they had intensely studied the market and understood the business opportunity. PlastiComp replied that if they had studied the market, they did not look out far enough to see the real opportunity, which is to create new market opportunities for their customers. In other words, market opportunities are not created idly, but for a fit to the market needs. Finally, the technology licensing and company performance serve as invaluable marketing purposes without the establishment of a conventional sales group.

In terms of the value pricing, new program strategies were based on the merits of individuals within the company. The "It all depends on everything" philosophy translates into an extremely fluid and adaptable environment for negotiations with external and internal customers. In this thinking, only the cost of business hours, employee hours and the use of materials and facilities are acknowledged as inviolate. However, the price of products or generally engineering output is not, since the value of such output and services varies with market conditions. It has allowed the company to adopt value pricing, rather than pricing based on the sum cost of the many components. It is their experience, that sales revenues equal that from a fixed pricing system. What is gained is the oft-repeated, yet seldom achieved slogan of "The customer comes first".

An extraordinary pay-off of this behavior is that a small company appears multi-faceted, which is the natural composition of any organization, but is rarely leveraged to their own advantage. At PlastiComp adaptive and accommodative behavior of the company employees is focused upon customer needs and desires in order to effect different organizational behaviors, tailored to individual customer expectations. Therefore, the company is rightfully alert to the sclerotic effects of enterprise resource planning software. Although these packages streamline operations and are probably much needed in global companies, their side effects cannot be ignored.

All in all, PlastiComp comes across as cultivating a participatory environment, with horizontal debates on company trajectory. We question how company growth will affect these behaviors. However, such doubts are based on an extrapolation of current organizations and their evolution that small companies grow to become big companies, which then branch out globally to end up as inflexible organizations. PlastiComp envisions devolving into small to medium business units organized on their business merits and embedded in the cultural environment that gives rise to them in the first place. It is therefore important to not imagine the future based on the limited precepts of today. The pay off for PlastiComp has been that it now successfully partners with multinational OEMs such as BASF, Samsung, Under Armour and others.

Case Study 3: Terrafore, Inc., USA Commercialization of Renewable Energy Technologies

Our third case study refers to Terrafore, a partnership that was formed to investigate energy programs. Terrafore has several years of experience in energy issues, including automated control of complex processes. Terrafore is presently working on sustainable energy usage. Research questions included: How can sustainable energy be assessed with methods other than costs or methods to optimize costs and ecological impact. The second research question is of a technical nature and illustrates (in retrospect) how underlying principles of PAR were successfully used to solve a complex manufacturing problem.

Sustainable or renewable energy such as solar energy when viewed with the lens of the profit and loss financial statement appear to be a costly proposition when compared with the conventional fossil energy sources. This is because there are no standards for allocating costs to natural resources. This study feels that it is largely a fundamental institutional problem associated with the ubiquitous Generally Accepted Accounting Principles (GAAP) accounting practices.

Ever increasing resources and energy demands by rapidly industrializing economies of China, India, Brazil and South-east Asia is leading to a noticeable change in environments such as the climate and loss in biological diversity due to habitat destruction, such as the slash and burn economies in the rain forests of the world. Furthermore, the conventional approach to handling waste streams by dilution does not work, as toxicity, whether chemical or otherwise accumulates in the least defended economy sectors. Thus, toxic chemicals end up in flora and fauna, thus poisoning the life chain. Sustainability in the broadest sense is an appeal for a new social order that revises institutional and organizational relationships, so that changes in economic, social and environmental domains are at once transparent and explicit. It is concerned with the embeddedness of industrial activity in the society and in the environment. When this view is adopted, sustainability requires that industries utilize resources at a sustainable rate. Responses to this concept have included systems thinking, such as total quality environmental management, eco-efficiency in production, license to operate and leadership positions in their industry in sustainability issues. Finally, for sustainability initiatives to impact our lives, it will require a shift in cognitive maps of organizations, which are composed of human beings, after all. Sustainability initiatives will be forged by a synthesis of the strategic paradox of organizational purpose – profitability vs. responsibility. Thus, as stated earlier, there is a need for selection methods other than cost, or methods, to optimize costs and ecological impact.

Furthermore, the use of terms such as ‘subsidies’ when associated with renewable energy creates a negative image for these sustainable resources. Recently, US administration announced a technological initiative for $1/Watt solar to get the costs to be competitive with fossil power sources. Even though the intent of this initiative is to challenge the technical community to reduce costs, it creates the impression that technological that technological innovations are required before these resources can be competitive. When PAR processes are applied, a horizontal research model is suggested, in which equal positions are formed for the various stakeholders. As this process goes beyond vested interests, it critically explores norms and beliefs such as the bottom line accounting practice of profit and loss. What emerged from such an exploration is the so-called, “triple-bottom line” where, in addition to the economical impact, the social and environmental impact is also measured. It was shown that the desired $1/watt solar power cost, in reality, could be higher if concomitant savings were realized in social and environmental categories. Thus jobs creation in the society in a new sector, a cleaner and quieter environment and so on, have to be quantified to truly assign a dollar value to solar energy per unit measure. Another way of introducing realistic measures of cost is to include the notion of the marginal utility of resources. Thus, the current use of natural resources such as fossil fuels does not take into account how the utility of these fuels is diminished in time. In contrast, solar energy provides an energy source of constant utility value.

As always, the devil is in the details – to date, there is no accepted measure of accounting for varying utility value. It is true that sustainable accounting methods have arbitrarily assigned a cost to depleting resources. Carbon-credit as a monetary instrument and legal tender is a good example. However, the difficulties encountered in its favor make it very clear that stakeholder participation with respect to multi-national agreements between the developed and developing parts of the world is incomplete. Therefore, as the classroom democracy project has shown, it is important to capture the concerns of the established actors, namely developed countries and the developing countries on a common understanding of energy cost. Global markets and finances have made it clear that stakeholder participation extends beyond national boundaries. Hence, our applied research ends as recommendations and not conclusions, as the required participation extends beyond that available to our means.

The next example addresses complexity science. It is a standalone example of the physical means of implementing complexity science as annunciated earlier in this paper. It is included here to emphasize the role of complexity in PAR. This example relates to the production of fiber-reinforced, polymer-matrix composites. These materials are produced in a series of batch processes, one of which involves the carbonization of the polymer matrix. Carbonization refers to the conversion of hydrocarbons or polymeric compounds into a network of carbon atoms. During this carbonization cycle, the rate of conversion is dependent on several independent variables, which also interact variously. However, to control this process a simple recipe is used.

Figure 1 shows such a recipe to process a part in the carbonization reactor. The part is heated at less than 2 degrees per minute and held for 10 hours at a specified temperature and then cooled. When engineers were queried they indicated that <2 deg /minute will take care of situations when the part contains excessive moisture. However, when the part contains low moisture, the part can be heated at much higher levels. This information was lacking in the recipe. This is a classic means and end problem. Recipes are only a means to achieve certain ends, the processing goals. That the information about these goals, or the ends, is completely missing in batch processing is a big handicap for the process engineer in the plant. The engineer is given just the *means* to work with, and the knowledge about the ends is limited to a few process experts or is lost as the process develops from the laboratory to the plant floor. If a recipe requires modification, the information about what must be achieved, from a processing perspective, is of utmost importance. Figure 2 shows the desired-state and action for this example. In-situ sensors were added to the process to assess these states. The intelligent controller relied on these in-situ sensors to capture real-time data or information, as well as the output of a model that predicted the kinetics of the conversion process. For the purposes of this report, it is useful to visualize this controller as a three-step processor at the data input-output level, where it unfreezes a specific environment so that it may characterize it, steers or moves it to a desired state and then refreezes the preferred state. At the knowledge level decision making is fuzzy, as the controller contemplates on how to navigate N possible states for the process.

Thus real world systems are seldom simple. However, the practical approach for addressing such complex systems has been to solve simpler approximations of the same. As we gain better understanding of nature and solutions to these problems, the drive has been to move up the complexity ladder. The reasons are many. In virtually all technological or social undertakings we are attempting to optimize several conflicting criteria – performance, cost, environmental impact, safety and so on. Complexity arises in part from the challenges posed by these desires. Complexity management requires us to exploit multiple knowledge sources and mechanisms to use the information (which are generally heuristic or non-linear) clustered in them. We are thus applying these techniques.

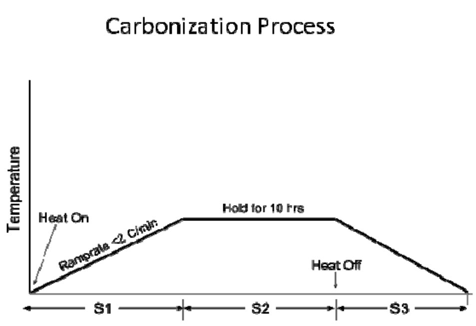

Figure 1. Recipe

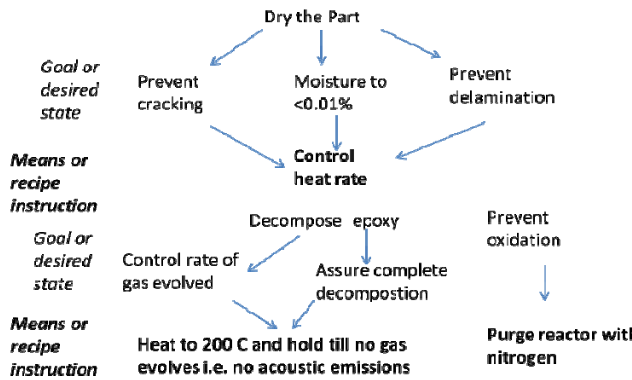

Figure 2. Desired Sates and Goals

REFLECTIONS ON COMPLEXITY THEORY AND ACTION RESEARCH

Based on these case studies, we are convinced that both complexity science and PAR have a lot to offer. Salient features of PAR are the horizontal, non-hierarchical relations which allow new knowledge and ideas for alternatives to merge freely, beyond the scope of vested interests. It includes a heterogeneous membership of different stakeholders, who recognize that they are equal to each other within the research group. PAR includes double loop learning, which facilitates in depth reflection and change. It integrates abstract, theoretical with practical knowledge and it facilitates shared processes of meaning making and decision taking. CT, in turn, allows to integrate non-linear, chaotic elements as well as various incompatible interests of a technical process in a research design and its subsequent technical products and procedures, as the Terrafore case study has shown. Both can be used independently, but, based on emergent research designs and grounded theory, they can be very usefully combined in order to create a powerful research project, which, as we have shown, enhances both social and technical organizations.

CONCLUSION

Modern society offers unknown possibilities which come together with highly complex social, technical and ecological problems. In the Netherlands PAR has contributed to theoretical and practical knowledge on how to stimulate social justice in the classroom. PlastiComp by using PAR principles, has grown to be an esteemed partner of large scale OEM's. It has furthermore developed a value-based pricing system, which keeps it in tune with the market. It now uses PAR to create an optimally prepared organization, capable of dealing with the challenges to do with scalar growth in terms of projects and partners. Since the company is loyal to its employees, it uses PAR to allow employees to continuously develop necessary skills and competencies, while integrating them in a horizontal structure of decision making. Terrafore develops sustainable forms of energy and is convinced that the success of new forms of energy requires double loop learning, reversing old practices by costing carbon footprint. Therefore, it requires introspection and a dialogue beyond vested interests in order to genuinely achieve an economic model based on the triple bottom line principles. It has made intelligent use of complexity theory in combination with PAR in order to successfully create batch processing and a compelling economic case for alternate energy usage. Our main recommendation is that academic research in PAR and complexity must be readily and constantly applied to real-life situations and not rest in academia.

REFERENCES

[1] Illerus, Knud (Ed.), **Contemporary Theories of Learning**. London: Routledge, 2009.

[2] Shani, A.B. & Pasmore, W.A. "Organizational Inquiry: Towards a New Model of the Action Research Process", in: D.D. Warrick (et al) **Contemporary Organizational Development. Current Thinking and Application,** Glenview, IL: Scott, Foresman, 1985, pp. 438-48.

[3] Spencer, L. & Spencer, S. **Competence at Work.** New York: John Wiley & Sons, 1993.

[4] Isaacs, W. **Dialogue and the Art of Thinking Together. A Pioneering Approach to Communicating in Business and in Life.** New York: Doubleday, 1999.

[5] Blaikie, N. **Designing Social Research. The Logic of Anticipation.** Cambridge, New York: Polity, 2010 (2^{nd} ed).

[6] De Lange, R., Schuman, H., Montesano Montessori, N., **Praktijkgericht Onderzoek voor Reflectieve Professionals,** Antwerpen: Garant, 2010.

[7] Montesano Montessori, N. "Researching classroom communications and relations in the light of social justice", offered for publication to the **Journal of European Action Research** on 14 September 2010 (accepted).

[8] Harvey, D. **Justice, Nature and the Geography of Difference,** Oxford: Blackwell, 1996.

[9] Slee, R. "Social Justice and the Changing Directions in Educational Research: the Case of Inclusive Education", **International Journal of Inclusive Education**, 5: 2, 2001, pp. 167-177.

[10] Lewin, K. "Frontiers in Group Dynamics", in **Human Relations,** June 1947, vol. 1, no 1, pp. 5-41.

[11] Edward, P. & N. Montesano Montessori (2011) "**A critical return to Lewin: exposing discourse and identification in a Participatory Action Research project"** accepted paper to be presented at the Organizational Change & Critical Management Conference, Naples, July 2011