Highlights

- Paper presents a conceptual framework and methodological guide for researching and understanding OR interventions.
- The paper outlines the main theoretical and methodological concerns that need to be appreciated in studying PSM interventions.
- The paper explores activity theory as an approach to study them.
- A case study describing the use of this approach is provided.

Understanding behaviour in problem structuring methods interventions with Activity Theory

Leroy White[1], Katharina Burger, Mike Yearworth

Leroy White, Warwick Business School, University of Warwick, Coventry CV4 7AL, leroy.white@wbs.ac.uk

Katharina Burger, Faculty of Engineering, University of Bristol, BS8 1TN, katharina.burger@bristol.ac.uk

Mike Yearworth, Faculty of Engineering, University of Bristol, mike.yearworth@bristol.ac.uk

Abstract

This article argues that OR interventions, particularly problem structuring methods (PSM), are complex events that cannot be understood by conventional methods alone. In this paper an alternative approach is introduced, where the units of analysis are the activity systems constituted by and constitutive of PSM interventions. The paper outlines the main theoretical and methodological concerns that need to be appreciated in studying PSM interventions. The paper then explores activity theory as an approach to study them. A case study describing the use of this approach is provided.

Keywords: Problem structuring methods; Behavioural OR; Activity theory; Collective intentionality

---

[1]Corresponding author Leroy White, Warwick Business School, University of Warwick. Email: Leroy.white@wbs.ac.uk

INTRODUCTION

Organizations and organizing are increasingly accomplished through the complex interaction of people, artefacts, instruments and practices (Clegg et al., 2002). Operational Research (OR) interventions are exemplary in this regard, but there is a gap in our knowledge in understanding the effect on people/outcomes, and the interventions *in situ* (Keys, 1997; Hämäläinen et al., 2013). In particular, there has been a dearth of strong theoretical and empirical studies on understanding OR interventions in the literature. Recently, however, there has been some attention on studying the effectiveness of OR interventions from social-constructivist and socio-material process perspectives (Franco, 2013; Keys, 1995; White, 2009, 2006), leading to important agendas regarding theory, behaviour and outcomes pertaining to (particularly soft) OR processes. We note that these studies have recognized that interventions are both temporally enacted affairs and concerned with becoming coordinated practices through the performance of using models as objects, but the studies are not adequate in developing the notion of behaviour in interventions. Therefore, some significant methodological and epistemological challenges remain (Connell, 2001; Eden, 1995; Packer and Goioechea, 2000; White, 2009, 2006).

We address the above challenges in the following ways. First, we build on recent interest in behaviour and OR, and in particular the interest in the concept of collective behaviour as a means for understanding how individuals working together perform effectively as an ensemble through the mediating role of models. Second, we introduce and explore the use of activity theory (AT) as one means to study interventions as complex interactions of people, objects, artefacts, and instruments in context. Specifically, our socio-material perspective differs from other approaches in that it introduces a view on the power dynamics in the unit of analysis of an activity system, which we believe helps to differentiate it from other methodologies.

Finally, we take as our example a case study of the participatory planning of smart city interventions for energy efficient city district redevelopment. Here we offer a focus on the level of proof, where many scholars of OR will agree that the nature of the link between OR processes, behaviour and outcomes has yet to be definitively established. Specifically, since a great deal of OR interventions are one-off (Keys, 1997), and attempt to tackle wicked

problems (Rittel and Weber, 1973) it becomes necessary to devise systematic techniques to ensure an adequate test of the efficacy of the approaches. We draw on an in-depth method using ethnomethodological techniques, including video analysis, to study the micro-processes of how the intervention under study was developing and used among the stakeholders involved (Paroutis et al, 2015; Heath, 1997).

Overall, we test the idea that OR interventions create the conditions for collective behaviour. In doing so, we contribute to the literature on understanding behaviour in OR processes, by employing the concepts from AT to explain the complex outcomes of (collective) OR processes, namely *social learning*.

THEORETICAL AND METHODOLOGICAL CONCERNS

As with all soft OR methods, the practice of building representations of the problem is conducted in a group, where the process is consultative and iterative. Behaviourally, the process provides a succession of models providing different perspectives, which contribute to a deepening understanding of the problem as new insight emerges. Also, the process uses the sense of unease among the problem owners about the present representation of the problem as a signal that further modelling may be needed. The question is: how can this practice (the relation between process, model and outcomes) be understood?

The study of OR interventions has taken many forms in recent years, including at the theoretical level focusing on the "Process of OR" through the lens of critical realism, constructivism and pragmatism (see Keys, 1995; Mingers, 2000; Ormerod, 2006; Taket and White, 2000a; White, 2006, to name but a few), and at the practical level through concerns for organizational learning (Sterman, 1989), shared mental models (Kunc and Morecroft, 2008), and more recently behavioural research (Hämäläinen et al., 2013). Such studies variously emphasize the complexity of OR methods and the significance of *doing* as well as of *deciding*, the social processes through which concepts and actions are negotiated, and the creative ways in which people use even the most abstract models and representations. However, few studies have tackled the foundational ideas underlying these processes directly (White, 2014), leaving the concept as largely metaphorical (Ackermann and Eden, 2011). The current work reviews some of the debates around the conceptual components of OR interventions to serve as a basis to position future research.

At a broader level, in organisational studies, most theories of interventions assume that individual and organizational behaviour is logical, goal seeking and self-interested (Powell and Di Maggio, 2012). However, in studies on soft OR interventions it is not difficult to show that neither individuals nor organisations are likely to act in such a way very often. Yet the expectation is for interventions to be intendedly rational and there is pressure for the stakeholders to act in a prospectively rational manner particularly where performance is visible and easily monitored. In contrast, there have been few attempts to articulate alternative views; the task is not simply an intellectual challenge but a practical one.

Phillips (1984) was one of the first to conceive of an alternative orientation for OR interventions. He introduced the term "requisite models" to distinguish a form of representation from descriptive, normative, optimal or satisficing modelling. He claimed that a model is requisite when "*it is a representation of the problem deemed sufficiently adequate by the decision makers to provide them with a useful guide to thinking about the problem*" (Phillips, 1982). In this way, requisite models do not prescribe action, - they are a guide to action, where action is a collective activity aiming at systems level improvement. This idea has been important in a number of OR studies, for example, (Franco and Montibeller, 2010) state that "*A consequence of considering a model as a facilitative learning mechanism is the challenge of assessing what constitutes a valid model and a good model solution. Probably the best answer to this issue is to employ the concept of building a requisite model (Phillips, 1984): one that contains sufficient knowledge and information to help the client group find a way forward".*

Phillips's (1984) argument for requisite models (and to focus on collective behaviour) was to counter the then in vogue research on judgement and decision making drawing on the classic work of behavioural economics (Hogarth, 1981, Simon, 1955 Kahneman and Tversky, 1984). The basis of their work is not that people have no idea how to take some decisions, but that they think they know, but are *wrong* by the conventional standards of rationality. The usual response is; if they are to do better, they first have to see the error of their ways. Indeed, many behavioural scholars think that the appropriate thing to do is to guide people in the direction they would want to bind themselves after taking expert advice. Thus, equipped with an understanding of behavioural findings of bounded rationality and

bounded self-control, experts should attempt to nudge people's choices in certain directions without eliminating freedom of choice (Sunstein and Thaler, 2003).

Other scholars have been critical of Kahneman and Tversky's work, including Gigerenzer (2006), who suggested that most behavioural research rather than focusing on "*plausible heuristics that explain everything and nothing—not even the conditions that trigger one heuristic rather than another*" (Gigerenzer, 1996), should be focusing on developing models that reveal mental processes that explain judgement. Similarly, Phillips claimed that the work of classical behavioural economics not only sees people as limited and biased in their judgements, but the research itself is limited and biased in its presumption that what people do is all that they can do. He argues that in the processes that search for requisite models, it is assumed that people are capable of constructing futures that deal adequately with uncertainty, risk and the complexity they face. Phillip's view is to focus on a more positive interpretation of behaviour that aims to meet the challenge of finding the conditions in which people can be "*intellectual athletes rather than intellectual cripples*", i.e. to create a notion of behaviour in OR on what people can do; and to encourage a "*science of better*" if you will (Mingers, 2007).

The idea that OR methods can mediate positive behaviour within groups is not a new idea. This has been acknowledged to some degree, for example by (Ackermann, 2012) who suggested that models in soft OR represent a facilitative device. Also, (Montibeller and Franco, 2007) discuss models as boundary objects. However, these are examples of a loose coupling of models and the actual situation, and therefore it is difficult to infer any theory of behaviour through representation.

In a further refinement, Franco (2013) applied the concept of *boundary objects* (based on Nonaka and Takeuchi (1995)) to facilitate the micro-level study of the dynamics in OR interventions. He suggested that the notion of cognitive affordances, based on the ecological psychology of Gibson (1979), may be useful for understanding the role of models in collective soft OR interventions (Franco, 2013). The idea is that the use of models that instantiate thought through systems of representation (e.g. Menary, 2006) may supply certain enduring material aspects which may play a special role in enabling the system to possess a given mental state (Clark, 2008). Franco discusses model affordances (Franco, 2013) as a source of behavioural consideration. However, there are some

limitations. First, given the focus on stakeholder engagement (Eden and Ackermann, 2013), the study could not adequately address the issues of power and contradiction (see Nicolini et al., 2012). Second, Franco's study while connecting the idea of boundary objects to learning, did not explore this at the collective level. When in fact Gibson sought to extend his ecological theory of affordances to the societal realm, he emphasised the need to reflect on collective behaviour: *"Social learning is inevitably moral, in an elementary sense of the term, and it is probably a mistake first to construct a behaviour theory without reference to social interaction, and then attach it only at the end* "(Gibson 1950, p.155). This is why we suggest that the concept of reflections on OR interventions requires an embedding in a theory and method that extends and enables a more reflexive attitude in order that power and collective behaviour can be explored.

In dealing with these limitations, the analytical interest thus could turn towards *the staging and orchestrating of problem structuring interventions that makes accountable, authoritative decision-making on behalf of clients and prospective users possible* (Goodman, 2013). This line of inquiry may serve to encourage the interrogation of various 'representatives' and 'representations' in, of, and around OR practice (White, 2009). Could this lead to a possible distinctive behavioural issue around representation as mediating the form and content of an intervention? There could also be a focus on political representation that seeks to establish whether the system of representation has conferred agency to the represented, i.e. whether the representation process has distributed agency throughout a system. In this way, the political sense of 'representation'—as the delegation of authority to speak and act on behalf of others (Latour, 1987; Taket and White, 2000b; White and Taket, 2000) is taken to be merged with a semiotic conception of a sign 'speaking' on behalf of its object (see Taket and White, 1994).

Models as semiotic resources form an increasingly important part of our understanding of the process, reflecting what some have termed the emergence of a problem structuring culture (Eden and Ackermann, 2013; Ackermann, 2012). This has also been referred to as the material agency of models and is an important part of the performativity of problem structuring processes (Franco, 2013; White, 2006) and provides coordination of interventions, often without those upon whom they are taking effect being knowledgeable (White, 2009). Models as such, do not cause or require action, but they may make some

behaviours more likely than others (Kaptelinin, 1996). Given the attention on models and modelling in the soft OR community, in developing a theoretical lens for the behavioural study of OR interventions, a strong analytical approach to objects and artefacts, such as '*documents, spaces, tools, and bodies that intervene in the production of identities, responsibilities, and capacities of project constituents*' (Goodman, 2013) would thus be desirable.

Actor-network theory (ANT), an approach developed by Callon, Latour and Law, within social studies of science has been extensively drawn on in the study of complex situations (Callon, 1996; Latour, 1992; Law, 1992). It takes as its primary focus the relationship between natural entities and social actors and seeks to recast our understanding of this relationship within a new epistemology. ANT considers both people and technologies as enacted through networks, in particular in terms of what people and things become as a result of their position in a network, and the power that emerges (Callon, 1986; Latour, 1992). Actor-networks are often highly dynamic and inherently unstable. They can be stabilised to some extent when people, technologies, roles, routines, and so on are aligned. This alignment is achieved through 'translation' (Latour, 1992). Actor-networks are heterogeneous and organically evolving open systems, and inscription devices (for example, models) may help to stabilise the network and thus shape and constrain the network. Researchers have used ANT to describe the engagement of groups of actors who have sought to define and inscribe particular codes and standards into particular technologies, and shown how once these have become part of the network, they are hard to reverse.

Following the arguments from Keys (1995), it is no surprise to find that some scholars of OR have been drawn to ANT as an example of socio-material analysis of interventions. ANT recommends that we locate interventions in a heterogeneous network of humans and non-humans actors (Latour, 1987; 1992) and it is the observable patterns of mutual interaction between actors that constitute the phenomena that Latour directs us to study. In response to the network building concept of Latour and his concept of immutable mobiles, Star & Griesemer (1989) proposed more mutable 'boundary objects' that facilitate translation efforts amongst different viewpoints and agendas in collective work. This has been taken up recently by OR researchers (e.g. Franco, 2013). The ability to enable cooperation without

consensus makes boundary objects attractive for the study of work across heterogeneous organisations.

Research incorporating ANT and boundary objects understands that interventions are not fixed, determining, or a mediating platform through which people interact and complete tasks, but are dynamic and entangled assemblages of the social and the technical, continually produced in practice (Orlikowski, 2005). These lenses offer analytical traction in viewing interventions with less focus on whether or how we use models to produce certain outcomes, and more on how stakeholders and models are interrelated in practice to produce (more or less) stable outcomes with certain effects in the world.

A criticism of ANT is that it has a 'flat ontology'. ANT holds that there are no pre-existing layers (such as 'structure' and 'agency'). By refusing more conceptually differentiated and refined analyses of institutional sources of power and inequality, ANT appears to have little to say about the systematic exclusion that prevents some social groups from having a voice in the design and use of technologies. Another criticism is ANT's assumption of 'symmetry' between humans and things. Assigning humans a comparable agentic status to technologies has led to concerns that human motives, desires and virtues could be beyond the analytic frame and that ethical questions may be evaded (Mutch, 2002). Yet, ANT's emphasis on the dynamic and relational aspects of an intervention is a useful lens for studying change and the unintended outcomes of interventions – including the complex and unpredictable interventions that are known to OR interventions (Keys, 1995; White, 2009). Thus, whilst ANT can help map the network and consider certain aspects of how power flows within it, it may not be the most suitable lens to answer micro-causal questions such as why – that is, through whose agency and enabled and constrained by which social structures – did the phenomenon in question emerge? For researchers who seek to answer such questions, ANT may provide conceptual tools and inspiration, but not without providing a theory of either human agency or the generative causality of social structures.

These important and recognized boundaries of the ANT and boundary object perspectives are important to address, especially, given the interest in generative behaviour in OR interventions. A central concern needs to be how relations of power are enacted-performed-(re)produced through discursive practices-representations-evocations (Traweek,

1992, p.441). Whilst it is recognized that none of the abovementioned perspectives provides conclusive suggestions for the treatment of power (Law 2009; Star & Griesemer 1989: 413; Kontinen, 2013), we introduce AT here that foregrounds a socio-cultural analysis of human activity and the analysis of micro-level political dynamics in workshop settings. AT draws attention to culturally and historically derived constructs such as rules, divison of labour and community which are dynamically related in the unit of analysis, the activity system, with the subject, the mediating artefacts and the activity object. Furthermore, in AT

> *"activity and the overlapping systems of activity are viewed as sites of domination, accommodation and resistance, as well as struggle […]. The notion of dialectical contradictions is central to [AT] and individual perspectives and interests are constantly at play in negotiating these contradictions". (Fenwick et al., 2015, p.12)*

In these features, it can be argued, that AT may retain a more humanist orientation than ANT (Fenwick et al., 2015, p.12). AT's emphasis on the generative (creative and voluntary) potential of human actors to develop problem resolution approaches is also evidenced "*in the clear delineation of non-human artefacts as bounded, distinct from humans, and while embedded in cultural histories, releated to the notion of mediating human activity*" (Fenwick, 2010). As such, to attend to the dynamics of PSM interventions, our theoretical approach draws on AT. We introduce AT as a novel way[1] of understanding representing and intervening through PSMs. Our use of AT is that primarily framed within the Scandinavian AT strand, developed by Engeström and colleagues (see (Engeström, 1987)). It enables the analysis of processes of knowledge co-creation (Blackler, 1995) and it is thus a powerful lens through which we can analyse most forms of human activity, including OR interventions.

With its background in psychology, AT also provides an adequate theoretical lens to conceptualise behaviour, particularly, intentionality and reflexivity, i.e. the "*intermediate institutional anatomy of each central actant*" and "*the historically accumulated durability, the interactive dynamics and the inner contradictions of local activity systems"* (Engeström, 2005a, p.55; Kaptelinin and Nardi, 2006). The goal of AT then is to understand the mental capabilities of actors and to analyse the cultural and technical aspects of human actions. AT also tries to trace the causes for problems in an activity system by exploring the

[1] AT has been previously instrumentalised in a 'soft dialectics' approach combining SSM and AT (Bratteteig and Øgrim, 1994), however without taking an enactment view on workshop activity (process) and only focusing on the problem structuring method.

contradicting/problematic relations between the elements in an activity system and the influence of these contradictions on the results of activity (outcome). The insights it provides into an activity, the role it ascribes to active participation, and the significance it attributes to incoherency and dilemma provide the basis for a framework for understanding OR interventions and behaviour.

In the following, we further develop our theoretical perspective by first discussing the aspect of AT relevant to our research problem. We subsequently build our approach to studying OR interventions by focusing on how collective or social learning is enacted in the on-going processes and use of models as artefacts. We extend this aspect of AT to study behaviour in OR interventions by focusing on intentionality. In particular we draw on insights into collective intentionality.

ACTIVITY THEORY

The central concerns of AT are the relationships between material action, mind and society; the approach explores links between thought, behaviour, individual actions and collective practices. Thus, AT is seen as rooted in practice (Schatzki, 2008). Practices constrain and enable the processes through which activity can occur, they influence how recognition of action is accorded and what types of relationship may be formed in an activity context (Packer & Goicoechea, 2000). The notion of 'activity' in AT is a more general concept than either the notion of an operation or action. The concept of activity draws attention to relationships between motives and the contexts of action, and invites enquiry into the processes through which people enact the actions in which they participate. For scholars of AT, the interest is in the relationship between mind and culture, where activity is the smallest unit of analysis possible, which preserves the link between mind in society and the coherence of different actions. The link this general approach promises with the current study on understanding OR processes is clear: the settings for different activities are not determined by objective features but are provided by those who engage in them. OR interventions are thus activities imposed on different situations by the participants themselves (Franco, 2013; White, 2006).

As stated earlier, we adopt Engeström's (1987) version of AT, which emphasizes how analysis of activity must develop from the study of material actions and communication

processes. Engeström's version of AT locates human agents, their objectives, and the tools and language they use, within their broader social and structural settings.

Insert Figure 1 here

Figure 1 depicts these relations. Here, it can be seen that in AT, the construction of the person as a subject occurs through engagement in an activity, in which interaction with others and with the world are mediated by different forms of representation, including language, conceptual models and other material artefacts. Subjects are thus constructed in social contexts, formed through practical activity and in relationships of aspiration and recognition (Packer & Goicoechea, 2000). Engeström distinguishes between different types of artefacts:

> *"The first type is what artefacts, used to identify and describe objects. The second type is how artefacts, used to guide and direct processes and procedures on, within, or between objects. The third type is why artefacts, used to diagnose and explain the properties and behaviour of objects. Finally, the fourth type is where to artefacts, used to envision the future state of potential development of objects, including institutions and social systems (Engeström, 2005a, p.320)*

A further distinction between different types of mediating artefacts is made, based on the differentiation between primary (directly used in production), secondary (internal and external representations of primary artefacts) and tertiary artefacts (imaginary artefacts) (Wartofsky, 1979)**.**

Insert Table 1 here

OR interventions can thus be considered as clusters of primary, secondary and tertiary artefacts, each class simultaneously mediating different elements of the intervention process (Bertelsen, 1998). Through the conceptual distinction between operation, action and activity AT can conceptualise reflexivity:

> *"Working up from actions to activity we may begin to grasp "the part of ourselves which we least understand and which answers the question 'Why do we act as we do?'"* (Harré, Clarke & De Carlo, 1985, p.30 in Engeström, 1996)

Furthermore, the distinction provides us with an analytical approach to get at the dynamic mechanisms in an OR workshop setting.

The idea of *mediation* via models is central to AT (Kaptelinin, 1996). At one level, models may include tools that mediate people's thoughts and behaviour. Conversely, people's thoughts also shape the artefacts produced and their usage. Mental models are artificial formations and social by nature (Vygotsky, 1981). They comprise language, mnemonic techniques, schemes, maps, drawings, signs, and other mental artefacts (John-Steiner and Mahn, 1996). In AT, the relationships between the subject(s) and activity, artefacts or tools always mediate the object, (i.e. it occurs in the activity). The mediating artefacts or tools are always required when a subject interacts with the world. Thus, the notion of mediation is central to Engeström's theory (Engeström, 1987). Mediation in this sense should not be understood to imply that the development of tools or language simply makes it easier to do things that were somehow going to get done anyway. On the contrary, the notion points to the occurrence of qualitatively new events, events that would not otherwise have been possible. Language is an important aspect of analysis of interventions because it may become 'materialised' in artefacts (Froschauer, 2009), and it may stabilise activity objects, for example through metaphorical objects (collective symbols) with drawing power for collective behaviour (Chiva and Alegre, 2005; Jäger, 2012). The complementary use of *"ideas from sociolinguistics and from the tradition of critical discourse analysis*" may be fruitful in *"connecting the general principles of studying power and the actual analysis of interaction in encounters"* (Kontinen, 2007, p.142) and so to trace inscribed motivations and power struggles (Kontinen, 2013). Power in AT is understood as *"relational and emergent in different strategies and tactics used in negotiation that bring together different interpretations, interests, and motivations of the actors participating in negotiations*" (Kontinen, 2007).

We suggest that PSMs are a form of social practice that could be understood as model-mediated activity (see Leontiev, 1981). In Engeström's model of AT (Engeström, 1987), there are three processes of mediation; of tools between subject and object, of rules between community and subject, and of the division of labour between community and object. These are presented as transforming the nature of the contexts within which people act. Where AT is unique, however, is in the emphasis it places on the suggestion that symbol-mediated

activity should not be studied as if it were 'for the mind alone'. As Engeström emphasizes, people act practically, moulding their material environments, and they do this not alone but in co-operation with others. Engeström (1987) introduced the notion of *community* as the collective that is interested in an object, *rules* which mediate the relationship between a community and the subject of an activity, and *division of labour* as the way the community is related to the object of the activity. Therefore, AT employs a collective, artefact-mediated and object-oriented view of activity systems (see Figure 2) (Cole et al., 1997; Engeström, 1999). Accordingly, central to AT is the conception of collective or *social learning*. This is a creative accomplishment, which can only be achieved by active participation (see Bandura, 1990). The suggestion is that learning occurs as people do more than they yet know how to do. The approach suggests that the ambiguities, uncertainties, and contradictions that are characteristic of the human condition can provide key opportunities for individual and collective development. This is also linked to a view of learning conceptualised as a collective activity '*when psychological functions contribute to the development of qualitatively new social functions'* (Schaal, 2009).

Necessary circumstances for such learning processes arise from the ambiguities and conflicts that can be found within and between activity systems. For example, Figure 2 shows two interacting activity systems, the minimum number required for activity system networks to evolve (Engeström, 1999). The activity object is a collective project that is stabilized by the shared tools, signs and procedures of the activity system. The activity object (object 3 in Figure 2) acts as a boundary object between the two activity systems. It is also conceptualised as "*visible, accessible, and cumulable – allowing participants to return time and again. There must be effective feedback from and exchange among the participants acting on the object" (*Engeström, 2009).

Figure 2 here

Finally, change and order in activity systems are continually negotiated in the multi-voiced and historicised social practices and the emerging activities that are aimed at overcoming contradictions (Engeström and Blackler, 2005). Contradictions may take place either inside the key constructs (e.g. subject) or between them (Engeström, 1999), or they may arise in networks of activity systems with respect to the object of the activity.

In sum, AT offers a powerful set of ideas that serves to integrate social constructivist developments in the understanding of OR (Keys, 1995; White, 2006), boundary object (Franco and Montibeller, 2010) and affordance-oriented perspectives (Franco, 2013). To summarize, the key aspects are:

(1) The concept of activity. People do not just think, they act on the world and they do this collectively. AT bridges the gap between motivation and action through processes of acting in the world (Kaptelinin and Nardi, 2006).

(2) The nature of activity systems. Mediating mechanisms, such as tools, models, language, social rules and the division of labour, transform the relationships between individuals and communities in collective activity. Such mechanisms are interwoven in a complex web of mutual interactions.

(3) Active participation. Actors learn by participating in activities and activity systems. This is a creative and interpretative and reflexive process. Such learning is likely to be tacit rather than explicit (Tsoukas, 2003). Collective or social learning occurs when the community of actors construct new conceptions of their actions and develop new activity systems.

(4) The prevalence of contradiction and dilemma. These are integral features of activity systems. They offer major opportunities for collective learning.

Extending AT: the dynamics of collective intentionality

Our objective is to understand OR interventions in terms of behavioural issues. We wish to show that AT offers a theoretical lens to relate empirical data to the scaffolding of social (or collective) learning. However, Engeström's AT orientation is only partially theorized in linking activity and behaviour. Building on the suggestion of other scholars (see (Tomasello, 2009)) the behavioural aspect of activity could be further explored through the notion of collective intentionality (Tuomela and Miller, 2009; Gordon and Theiner, forthcoming). It is suggested that collective intentionality enables the reaching out that occurs when people operate across the boundaries of discrete activity systems. This was partially explored by Engeström in the AT literature as 'Collaborative intentionality capital' (Engeström, 2008). We follow the suggestion that tracing the dynamics in 'Objects of Activity' constitutes a way of exploring the development of *collective intentionality* (Tuomela, 2005)*:*

> *"The idea of we-intentionality is that humans have the capacity to not only recognise another agent's intention but that humans can join intentions thus making cooperation not an accidental by product of behaviour or an aberration of behaviour, forced by the threat of punishment. Rather, humans are hard wired to cooperate, sharing goals and making plans together to achieve those common goals" (Tomasello, 2009).*

Collective intentionality in this sense thus means "*thinking and acting (e.g. believing, intending, performing joint actions) as members of a group (however fleeting)"* (Tuomela, 2005) (see also (Tuomela, 1995)) through collaborative interactions in which participants have a shared goal and coordinated action roles for pursuing that shared goal. A we-intention (Tuomela and Miller, 1988) "*consists of the intention of an individual to do her or his part in some prospective action of the group, along with some belief about the we-intentions of the other members of the group and about the opportunities for actions. These we-intentions make intentional joint action possible*" (Preston, 2013). We suggest that AT may help to understand how subjects and communities develop collective intentionality through activity aimed towards a 'partially fragmented and partially disputed' activity object (Miettinen and Virkkunen, 2005), mediated by artefacts, rules and division of labour. This is further expanded upon in the case analysis section of this paper.

Comparison between ANT and AT

Finally, before moving towards our empirical case, it is worth summarising the similarities and differences between AT and ANT. Without a doubt, there are many points of contact between ANT and AT (Miettinen, 1999; Schaal, 2009; Shaffer and Clinton, 2006, 2005). They both comprise a unique combination of material, mental, social, institutional and historical factors and provide analytical tools to understand the nature of the reciprocal action-shaping of humans and nonhumans (Andrade and Ekundayo, 2011). Theoretically, AT if not similar, is very close to ANT, particularly in the adoption of theories of language and semiotics (Miettinen , 1995; Miettinen & Virkkunen, 2005; Latour, 1987), where humans create a sign system which, in the first place, is used to co-ordinate actions with those of others. This provides the essential link through which activity theorists explore the mediated relationships between culture and mental functioning.

One of the most significant differences for the study of soft OR interventions lies in ANT's principle of generalised symmetry and its consequences for understanding agency and intentionality in humans and non-humans (Latour, 1996a; Lynch, 1996; Engeström, 1996; Latour, 1996b). In ANT, both humans and objects can modify a state of affairs, however, only humans are empowered with intentionality (Andrade, 2012; Andrade & Urquhart, 2010). The ANT principle of symmetry appears to lead away from specific human capacities such as "*intentionality, expression, powers of invention and 'fabulation'*" (Turner, 2011) as "*any thing or human being, human intention, consciousness, desire, etc. emerges and oscillates through various translations at play in material network effects*" (Fenwick, 2010).

From the point of view of AT, ANT's conceptualisation of intentionality as a network effect contrasts sharply with the emphasis of the creative, generative competence of human actors (Strübing, 2005, p.333). In a social psychological view of intentionality, a human agent is characterised as one that can "*intentionally make things happen by one's action*" (Bandura, 2001, p. 2). According to Bandura (2001, p.1), the core features of agency are "*intentionality, forethought, self-regulation […] and self-reflectiveness*". Applied to collective social learning, AT thus highlights human intentionality as a pre-requisite for the collective generative struggle with contradictions.

> "*Collective intentions to perform something together involve intentional dependencies between agents. These can vary in strength, but the central tenet here is that the participants voluntarily create relevant action-dependency.* "(Tuomela, 2000)

In Nardi's (1996) view, AT's view about the primacy of human agency has a number of benefits over a symmetrical view of human and nonhuman agency:

> *"The activity theory position would seem to hold greater potential for leading to a more responsible technology design in which people are viewed as active beings in control of their tools for creative purposes rather than as automatons whose operations are to be automated away, or nodes whose rights to privacy and dignity are not guaranteed" (Nardi, 1996, p.87).*

In place of ANT's symmetrical human and nonhuman actants, AT offers a stratified approach to analysing agency arising in performances in workshop settings. Figure 3 shows a possible overlay of ANT's mediators and intermediaries on AT's activity system notation to illustrate how AT spans open a field of analytic opportunities by conceptualising an embedded human subject in a field of relationships between mediators and intermediaries.

Figure 3 here

Engeström suggests that both the vertical and horizontal relations in activity systems and activity networks should be studied, so that institutional anatomy of each actor is revealed- i.e. the historically accumulated durability, the interactive dynamic and the internal contradictions of local activity systems.

Overall, ANT and AT offer different –and at times potentially complementary (Andrade & Ekundayo, 2012)- analytical 'toolboxes' to study how goal-directed collective behaviour, mediated by and inscribed into emerging artefacts, may be brought about through problem structuring interventions. An additional comparative overview of key concepts in AT, ANT and comparing those with boundary objects, is provided in *Appendix 1 [Table 2].*

METHODOLOGY

Our approach for the study aligns with suggestions for developing schemes and theories for intervention research by focusing on what participants in interventions do with each other, and with what tools, and for what purposes, and also with what matters to the participants, and how participants perform doing and saying things with what effects (Sandberg and Tsoukas, 2011). In order to achieve the above, a systematic field study was conducted of the intervention with stakeholders using a PSM. This included questionnaires, interviews and observations. However, our main method for analysing the case was the use of videos.

Videotaping was chosen to collect data in order to be able to reconstruct the micro-level interactions between participants through language and other tools used in the PSM modelling process and to obtain a rich permanent primary record that could be shared between the researchers. Video data collection was chosen with the intention to undertake theorising that is "*responsive to the phenomenon itself rather than to the characteristics of the representational systems that reconstruct it*" (Jordan and Henderson, 1995, p.51).

The data analysis proceeded via transcription of the conversations of the participants in the different groups. Our analysis of the video data then focused on key incidents (Emerson, 2004). We detail our analysis using video in the appendices. Three stages of analysis was used.

The first stage involved reviewing the empirical material and producing basic summaries of what was happening while the workshops were taking place. The summaries provided contextual information informing us, at the broadest level of what was going on. In keeping with Sandberg and Tsoukas's (2011) suggestions, the summaries focused on the unfolding nature of the case, concentrating on the specific details of the conduct of the workshops.

In the second stage of analysis, AT formed the basis of the lens against which the empirical material was compared. This analysis mainly focused on 'activity'. Thus, the unit of analysis is neither the individual nor the organization, but the system of activity (in our words, the intervention) (Engeström, 2001; Cobb and Bowers, 1999). We therefore attended to the content of speech, and turn taking (Greeno, 1998), remembering that the unit of analysis is not the perceived object or linguistic input, but focused on the active participant, or the activity itself (Van Lier, 2000). Here, the focus is on the explanatory properties devised to understand perception and action, and must have a relational nature (Davids & Araújo, 2010). Engeström's Activity Triangle (Figure 1) was used to visualise AT system transformations in networks (Engeström, 2005). Finally, AT analytical approaches may be complemented by artefact analysis (Hodder, 2012) and conversation analysis (Berkowitz and Others, 1986) to provide further in-depth knowledge of activity dynamics. However, this was not conducted on the material presented here.

The third stage drew on the analyses above to guide analysis of the data in terms of agency within the intervention. We compared and contrasted the data, refining the analysis and so obtaining detailed findings of the intervention as it unfolded. It is here that participants with different knowledge, skills, and experience can be seen to be reaching out to each other through explanations and sharing of prior knowledge, in our case, for example, knowledge about ways to engage with site owners in problem solution and learning processes. Diversity in workshop settings thus becomes a necessary pre-requisite/principle of practice for social learning to occur.

The key incident presented is taken from the first workshop of an EU Smart Cities project, which took place in March 2014. The following section presents the details of the case study and application of AT to the study of a PSM intervention. Details of our coding and analysis of a video excerpt are given in Appendix 2.

CASE STUDY

The case study describes an intervention in which a PSM was employed with multiple stakeholders to explore the use of systems thinking for energy efficient planning in the City of Bristol in South West England. The case study took place during 2014, and hereafter will be referred to as the STEEP project. The first part of the case describes the genesis of the work and the relevant context. The intervention itself is then described, which covers the processes and outputs of the work. A final part forms the analysis of the case. The details of the analysis are based on video recordings taken during the intervention. The analysis follows one of the participating stakeholder groups throughout the workshop. Activity systems analysis is applied based on a loose interpretation of (Jonassen and Land, 2012)'s operationalization of the theory. The analysis of the case is meant to be illustrative rather than conclusive and only represents a partial analysis of the case.

Background

The context for the case is the growing concern for securing sustainable, reliable, and affordable energy systems in EU-countries that seek to address climate change risks by meeting EU 2020 carbon reduction targets. Opportunities for change towards lower carbon energy systems arise from the convergence of ubiquitous IT systems with decentralised energy technologies that create new complementarities of small-scale, local technologies with traditional networked infrastructures. Cities are perceived to be ideal test beds due to their limited scale, their diversity and hence opportunities for learning about the complexity of socio-cultural practice change that accompanies technology transitions. The STEEP project (Systems Thinking for Energy Efficient Planning) (STEEP, 2011) is an EU FP7 project that seeks to identify innovative interventions for city district energy planning that could be tested in the partnering cities and then have wider significance for cross-city learning.

The City of Bristol, in South-West England, is one of the partnering cities in the project, and a representative of the local council manages the project as part of the council's smart city programme portfolio. In its Smart City Programme, the City Council formulates the aim that Bristol should be in the top 20 European cities by 2020 and has made a clear

commitment to create a world-class and inclusive green-digital economy. The aim is to use smart technologies to reduce CO_2 emissions by 40% by 2020 from a 2005 baseline, whilst also meeting the city council's social and economic objectives (Bristol City Council, 2012).

The 'sustainable' entrepreneurial city that is competing in the market place for intellectual resources is a dominant model of urban development in the UK (Nurse and North, 2013). It is predicated on the pursuit of economic growth and visions of low carbon cities become part of a sustainable development agenda. Local decision makers may pursue low carbon as an opportunity to create new jobs in the area, apply technology fixes to meet national emission targets and focus on stimulating the low carbon industry which is assumed to be a growth sector (North, 2013).

It is against this background that the STEEP project was set-up (Figure 4). The project partners in Bristol comprise the local university, an engineering consultancy, a third sector organisation with expertise in energy modelling, and the local council. The project proposal document (STEEP, 2011) states that the project's specific objectives are:

- To enable all participants cities and partners to learn from the successful and unsuccessful experiences of other cities and experts,
- To integrate all stakeholders in smart city plan definition: Public administrations, policy makers, technology providers, financial organisations, Enterprises and citizens
- To better understand the complex energy, resources, social and economic flows and their relationships,
- To have a clear picture on the number, effectiveness, cost and interdependence of the possible smart city interventions and projects,
- To disseminate or application plan to other similar cities at the European scale.

Figure 4 here

The Bristol Temple Quarter Enterprise Zone (BTQEZ) is a designated regeneration area that aims to attract businesses through reduced business rates, encourages development through a relaxed planning application processes, and facilitates regeneration through enabling infrastructure such as investment in transport and heating systems.

The design of the workshops was an attempt to surface issues about inclusivity of engagement in the debate about proposed actions. The control of a workshop invitation process can be used to constrain the scope or ambition of the transformational goal right at the start of the process by the owner pre-judging what might be desirable and feasible action. The formation of a stakeholder group and the setting of the transformational goal are necessarily co-dependent activities. In setting the original scope for the transformation, Bristol City Council suggested a particular group of stakeholders that they thought should be represented in the group model building workshops and they were duly invited to take part. Whilst this could be considered as an exercise in control at an early stage to constrain ambition it was in fact a deliberate attempt to widen participation beyond what could be labelled as the usual inner circle of decision makers. Bristol City Council were very open to the idea of the workshops acting as a forum in which the views of broader set of stakeholders, such as community groups, could be aired and debated. In this respect the whole process represented a novel approach to widening participation in the energy planning process and resolving one of its past failings.

Workshop description

During the first stages of the STEEP project, a group model-building workshop was held to facilitate the exploration of aspects relevant to systemic energy planning for the District Modelling of the BTQEZ. This was the first of three planned.

The workshop was attended by representatives of technology manufacturing companies, infrastructure operators, third-sector organisations with an interest in energy and low carbon development in Bristol, consultancies (multi-disciplinary engineering firms and architects), local authority employees and University academics. The invitations to participate were sent to a variety of organisations who were known to the project partners to have an interest in and/or relevant expertise for redevelopment projects in Bristol.

The workshop began with a BCC representative setting the context, followed by an explanation of the methodology by a University academic. Participants were provided with hand-outs of the outline spatial framework for the zone and high level draft models that had been agreed amongst the STEEP project partners prior to the workshop on the basis of the project's perceived objectives and an analysis of existing documentation about the energy planning process (Vennix 1996).

STEEP employs Hierarchical Process Modelling to structure the problem situation (Davis et al., 2010) that allowed participants to take a wide view of 'energy', including building types and usage profiles, infrastructure systems and technology, movement/transport mix, thereby considering social practices (the changing nature of work in networking hubs, an increasing awareness of sustainable energy behaviours and environmentally and health-friendly travel choices).

Case Analysis

The case study can be conceptualised as an activity system as the participants are active in the shaping and reshaping of the problem representation assisted by auxiliary artefacts, enabling distributed agency towards the projects' objectives, i.e. the activity object of 'achieving a zero carbon BTQEZ'. Collaboration among the participants with varying expertise necessitates a dynamic, dialogic relationship between the multiple actors; it is a relationship characterized by collaborative and discursive construction of tasks (Engeström, 2004). Heterogeneous groups are typical of a PSM intervention but are radically different from conventional teams or communities of practice (Lave and Wenger, 1991) in that membership at the periphery is fluid. In the intervention work, participants are required to recognize and engage with different goals of action and different expertise distributed across group members using models or boundary objects to mediate their actions.

The activity object in action

The overall activity object was to develop an integrated approach to low carbon development of the Enterprise Zone. In the first task, groups were asked to identify 'missing processes' from the template model (a task to stimulate debate) and then, following the structured process mapping methodology, to develop their own extension of the model using post-it notes and the flipchart.

The top-level process of the model was 'achieving a zero carbon BTQEZ', which had been identified as the overarching target for the STEEP project by the project partners during a prior workshop. This top level process caused controversy and was met with rejection by many participants for a) being too vague to mean anything due to a lack of measurements, b) being unrealistic based on knowledge about technological, financial, commercial and

operational difficulties in developing districts to become lower (not low or zero) carbon zones, and c) as being reductionist due to its lack of consideration for other, possibly equally – or more- important, economic and social objectives for the zone's redevelopment.

The top-level process thus shows the qualities of an activity object, as "*objects and motives […] appear to be vague, fuzzy, multi-faceted, amoeba-like and often fragmented or contested. The paradox is that objects/motives give directionality, purpose and meaning to the collective activity, yet they are frustratingly elusive*" (Engeström, 2005a, p.93). The statement provided a stimulus for expansive learning and the generation of creative alternative paths for action as it revealed contradictions inherent in complex planning situations such as low carbon transitions.

Following one group through the workshop

The workshop overall could be described as one activity system. However, for the purpose of this analysis, we draw the boundaries around the five different groups in which the participants were split for the purpose of the group model building exercises. The facilitator created the groups with a focus on preserving heterogeneity of participants based on organisational affiliation. This analysis follows one group to exemplify the application of AT in the study of PSM interventions. The selected group had four members: a representative from an international engineering manufacturer (S1), a railway engineering company (S2) [BTQEZ has Bristol's main railway station in its centre], an energy charity representative [part of the STEEP project team] (S3) and a Council Representative (S4) (Figure 7).

Participants were provided with a high level model as a starting point, which had been developed by the project partners (University, City Council, Energy Charity, Engineering Consultancy) during a training workshop, using HPM as well. Figure 5 shows the template model as well as the segment that participants decided to expand.

Figure 5 here

During the workshop, participants developed a new model segment, which is depicted in figure 6, after having undergone computer processing post-workshop.

Figure 6 here

The group deconstructed the problem as it had been presented to them by critically reviewing and changing the template model, in order to then reconstruct their own representation of the problem situation focused by a shared objective.

The process of modelling

The process may be described as de-constructing and co-constructing an activity system. Applying Engeström's triangular notation of activity systems, the activity systems of the participants in the group at the start of the group workshop can be depicted as shown in figure 7.

Figure 7 here

From Figure 7 it can be seen that the object 'Achieving a zero carbon BTQEZ' had to be made intelligible by the participants in order to be interpreted or subverted in a way that would have sufficient drawing power to create a new activity system from the interdependence arising between the participants through the workshop, given the task to consider the activity object as shared. As such, the participants challenged the activity object that was suggested (achieving a zero carbon zone) and focused on a sub-object that could be shared, and then constructed an activity system that would plausibly pursue the chosen process (engaging site owners) (see Figure 8). The new system represents all organisations/subjects that were represented by participants in the exercise.

Figure 8 here

From an AT perspective, the group's plans unfold in an activity system with a clear *object* as formulated in Figure 8. The object is not only an expression of the participants' beliefs, but it is also important for the way in which they interact because it has the potential to reduce the number of different motivations in the group. By making the object of their work explicit, the participants restrict widening their group in order to delineate their co-constructed activity system.

Towards collective intentionality?

Analysing the micro-level dynamics of interaction, we suggest that the development of we-intentions (Tuomela, 2013) may be observable from the participants' in situ group model building activity.

Engeström (2008, p.225) suggested that in order to study collective intentionality it is necessary to observe processes of "*dwell[ing] in the object, connect[ing] and reciprocat[ing] across boundaries.*" In accordance with Nicolini (zoom in/zoom out) (Nicolini, 2009), we suggest that the duration of this longitudinal relationship is relative to the episodes studied and propose a multi-layered model of conversation episodes in group model building (a couple of seconds/minutes, immediate) and at a higher level of feedback rounds between groups (a couple of minutes per group, in rounds spaced by hours of modelling) which could be extended to levels between workshops (March – June) as well as between projects and the smart city programme.

Drawing on transcripts (Carley 1997, Kiekel et al. 2001) from the conversations and interactions between participants during the group model building phases and from the group's feedback rounds, we aim to show how the conditions for we-intentionality may be met and thus how the problem structuring process is conducive to collective intentions becoming emergent.

The following excerpt shows a group discussion around carbon targets for the zone. It exemplifies the identification of contradictions (different organisations have different levels carbon targets), which are partially related to the size (and hence type of outlook (short vs long term)) of the different companies. The participants identify that a process to deal with the differences, without distorting competition and safeguarding an economically viable enterprise zone with both small, innovative and large, stable businesses, is needed. Furthermore, the rules and division of labour are implicit in the situation as the City Council can influence the setting of targets whilst companies are likely to choose their location based on strategic considerations which may include opportunities for clustering and/or reduced business rates, potentially making the enterprise zone attractive.

S2 Part of it is also balancing …spent… *[pointing to a process box on the flipchart]* so that's about resourcing/alliancing what you're able to do with what they're able to do… if I've got a 10% carbon reduction target, and you're aiming for 20 *[extended arm establishing connection with S3]…* how do we align our targets?

	And also how do you align that with the targets that investors have?
S1	And also how do you align them with the financial requirements? *[pointing at a post-it note on the flipchart]*
S2	And also.. we're talking here about a long term process.. most companies live hand to mouth, and the only thing they worry about it the financial statement at the end of the year.. because that means that we've got a job next year.
S4	But we'll be looking to develop the Enterprise Zone not just with small companies …
S2	But even the big ones…
S0	..are you saying….
S4	There is an aspiration of a carbon neutral development, which isn't bought into necessarily…
S0	So the question is.. how exactly would you overcome that? You know the disconnect, the gulf between those participating in the development of the zone? *[pointing at post-it on flipchart "Engaging people at the earliest opportunity"]*
S1	I think that you will have a mix of smaller and larger companies, you can't just… you have to have innovation as well, so somehow having the engagement too is important.. the small companies are riskier with innovation, because they can … and also the University has links
S3	[adding post-it note up to model: "Establishing organisational-specific targets/drivers & Aligning with TQEZ Goals"].
S1	So it's engaging all the different groups in the task

In the subsequent analysis we aim to show that Tuomela & Miller's (1988) conditions for we-intentions – as a minimum between two participants A and B - develop during the problem structuring process. Hence, we view collective intentionality as a sequence of individual intentions related in a certain way (Becchio and Bertone, 2004) and we adopt the following conditions and notation:

(a) A intends to do his/her part of X (IaXa).
(b) A believes that B will do his/her (B's) part (BaXb).
(c) A believes that B believes that he/she (A) will do his/her part (BaBbXa).

X is used to denote the joint task, Xa to denote agent A's part of X, Ia and Ba to respectively denote A's intention and belief. A we intention (WI) between A and B consists of (IaXa∧BaXb∧BaBbXa) in A's mind and (IbXb∧BbXa∧BbBaXb) in B's mind (Kaano et al., 2003).

In our example, the joint task (X) is focused around the partially shared and partially contested activity object (achieving a zero-carbon enterprise zone). S2 (henceforth A), representing a company with assets in the zone, intends to be part of a zone that will have

shared targets to become operationally lower carbon (IaXa). S4 (henceforth B), representing the City Council, intends to achieve a carbon neutral development (IbXb). It is reasonable for A to believe that B will do his part (setting targets) under the constraints that buy-in from companies is needed, and that for economic vitality, both small and large companies need to be in the zone (BaXb). It is also reasonable for B to believe that A will do his part (meet targets) under the constraint that the business continuity needs to be achievable under the targets (BbXa). Finally, we make the assumptions that A may infer Bs intention to collaborate in the accomplishment of the joint activity from Bs presence and participation in the workshop, and Bs utterances/speech acts and the historically derived rules and the existing division of labour that constrains the range of relevant/possible actions, and vice versa, so that BaBbXa∧BbBaXb are met. In this situation then, the we-intention to engage all the different stakeholders [small and large companies, with high and low innovation potential and short-term vs long-term investment horizons] in the joint activity [achieving a zero carbon zone] through a discussion about differentiation of targets [lower for smaller companies to be able to contribute to/be/remain in the zone] emerges.

Zooming out from the micro-level conversation within the group towards the feedback rounds between the groups, we furthermore suggest that traces of a stronger form of we-intentionality become visible. As part of the method, the groups provided feedback in three rounds (deconstructing, focusing, co-constructing). We suggest that the scripted feedback sessions in the workshop helped to positively update the mutual beliefs through explicit communication and observable behaviour during the presentations.

The quotes illustrate moments that we consider relevant to the further development of emerging we-intentionality.

> Round 1 - "*And the things **we asked**, was expanding the managing relationships box, including existing building owners, such as [X], and **we are here**, we have an existing building in there, we're not going to be knocking it down, building a new building, it's 150 years old, it is here to stay. Being as it is that case, how's that going to be considered in achieving a zero carbon solution?*"

In round 1 the quote suggests that the speaker speaks on behalf of his company (*we are here*) as well as a member of the group of stakeholders who are part of the his model-

building group *(we asked).* This suggests that A is functioning qua member of the group (g), which as a minimum contains A and B,

> Round 2 - so **we've decided** to focus on what **we thought** was a bit of a missing process there, next to managing relationships, the potential investors and developers, we thought about existing site owners, so people in the Temple Quarter Enterprise zone ***that are there already*.** Some of them might be developing their own buildings, others might not be. But **we've decided** to put in extra processes there, *engaging existing sites and owners*, so how do you actually approach them? How do you get them engaged in the process? […] So the phrase came up, alliancing between stakeholders in that sense, around that governance and funding issue.

In round 2, in particular the section "*people* […] *that are there already"* which is about '*engaging existing sites and owners'* is important because A and B are part of the group of people '*that are already there'* with assets and land in the zone. Given the use of the language '*we've decided*', we can suggest that A and B intend to participate in the satisfaction of the intention for the group (g),

> Round 3 - okay, so just focusing on the red dots really, to keep it brief. First of all, you know alliancing between stakeholders - we thought that this is probably not really happening. *There needs to be a sort of targeted subgroup, of maybe key stakeholders, in order to start talking about being strategic and planning ahead. […]*

Finally, round 3 of the workshop feedback suggests that A presupposes that the agents in the group (at least A and B) collectively accept the development of shared targets as their intention for satisfying the interests (achieving a low carbon BTQEZ) of group (g).

This suggests that the activity object (the zero carbon zone) draws participants to *act toward the same goal so that the group can be said to 'intend' the goal in virtue of generating a collective state by their interdependent behaviour* (Tuomela, 2013, p.33). This We-intention (WI) is characterised by the contradictions it holds together, in other words it emerged in the object-oriented activity of the participants (figure 8). The material inscription of it in the model as an artefact is also observable (participants including a post it note on the flipchart), as is the co-creation of the artefact in the process (inscribing we-intentions into it) of modelling (Figures 6 and 8).

Lastly, to trace how we-intentions from workshop settings may develop further, we return to Engeström's suggestions of a spatio-temporal (longitudinal) dwelling in the object.

The workshop reported in this paper only constituted the first of a series of group model building workshops and only implemented the first part of the methodology (issue identification and prioritisation). The second workshop implemented the HPM steps focused on option development. After the first workshop, the models were transcribed and included in a higher-level systems level model. This documented the need to develop processes to engage with existing site- and building owners in the zone to consider collaborative approaches for low carbon redevelopment. Not only did this 'we intention' thus become part of the subsequent workshop where it was retained and further refined, it also became clear that relevant research (business models) was already on-going to identify ways of facilitating engagement.

Activity objects and Learning at the collective level

The above episode also highlights the role of artefact-mediated activity on different planes (Rogoff, 2008). Collaborative learning thus creates interdependencies and complex relationships, which facilitate the development of communication and interaction. It enables the co-constructive development of knowledge and solution proposals. The participants can take into account the knowledge and perspectives of other contributors and can thus develop their own standpoint in the discourse with other actors. Through interaction with participants, learning becomes an active process.

Figure 9 here

In AT terms, this process could alternatively be conceptualised as a shared learning process (Figure 9) from individual rules (company targets) towards rules for a collective (the zone's users) that are negotiated in a new activity system (stakeholder group to be set up). Participants in the group thus abstract from their individual positions and models towards a methodology of engagement, considering the division of labour (SMEs, large businesses, the local council), their role as part of a community in a shared location (designated redevelopment zone) and the need to establish/re-negotiate rules together.

The application of AT to reflect on the process and content of the intervention has sought to demonstrate the flexibility of the conceptual entities that constitute an activity system and ATs ability to describe and visualise processes of co-creation of knowledge in activity system networks. The application of AT to one group was undertaken to exemplify the

potential benefits of applying AT and to understand the progressive development of shared object-oriented intentions. Furthermore, at a meta-level, to reflect on scaffolding of the workshop, AT could be applied to describe the PSM process in the workshop (Figure 10)

Figure 10 here

Lastly, through more in-depth analysis further detail could be provided

- By making explicit the stages of identifying contradictions, multivoicedness, and historicity through conversation analysis of the model building process and also in the reception of the constructed model by the other groups;
- By comparing the newly constructed activity systems across the different groups;
- By studying conversation analysis between participants in-depth in order to trace the emergence of the elements of the new activity model.
- By making explicit the material, social and linguistic infrastructures (Star, 1999) through artefact, interaction and discourse analysis. In this particular case, this might include a critical analysis of the UK planning system, the specific status of an enterprise zone as an instrument for accelerated economic recovery through reduced business rates, existing business associations and advisory boards in and for the zone, as well as an analysis of the terminology surrounding 'low carbon development' and smart city transitions.

DISCUSSION

The inconsistency of evidence from prior studies suggests that the mechanisms associated with OR interventions represent a significantly more complex phenomenon than previously understood (Midgley et al., 2013). Yet, despite calls for more research in understanding OR interventions (Keys, 1995; White, 2006; Mingers, 2011), we still know little of how the micro-processes of interventions are exhibited in OR practices, or the performance or behavioural effects of the adoption of practices on organizational interventions, although there is a growing number of studies exploring the effectiveness of OR interventions from a socio-material process perspective.

We addressed the research gaps in a number of ways. First, we built on theoretical interest in Behavioural OR (Hämäläinen et al, 2013), and in particular the interest in

understanding how individuals working together perform effectively as an ensemble through the mediating role of the model. Second, we briefly reviewed well-established ideas such as ANT and in comparison introduced AT as one means to study interventions as complex interactions of people, objects, artefacts, and instruments in context. This provided a theoretical orientation that guided the study of an intervention in a different way. To understand interventions it is necessary to study collaborative group activity, observe interactions and examine the artefacts produced. This is because AT assumes that reality is co-constructed through socio-cultural object-oriented activity. We then examined a case study of the participatory planning of smart city interventions for energy efficient city district redevelopment. Finally, the premise of the paper is that most OR interventions occur sporadically, normally as one-offs, and that they are therefore difficult to appraise using traditional methods. They are also complex events in which subjects constitute and are constituted in the process of engagement (Keys, 1997). We devised a systematic approach to ensure an adequate test of the efficacy of the approaches used in the intervention. In doing so, we contribute to the literature on understanding the OR interventions, by employing the concepts from AT to explain the complex outcomes of (collective) OR processes, namely *social or collective learning*. Collective learning arises at the system level through the distributed construction of reality that is stabilised through artefacts, including language, instruments, visualised models, written agreements and rules for action, with shared or intersubjective lifeworlds resulting from internalisation and externalisation (Kaptelinin and Nardi, 1997) of meanings by subjects and communities. Such assumptions about interventions could lead to research designs and research practices that encourage richer, deeper insights into PSM practices. A further contribution is the extension of Engeström's collaborative intentionality capital at the micro-level, where AT may be used to analyse empirical data to make processes of the emergence of we-intentionality intelligible.

A central finding concerns activity objects and power, where previous studies could not adequately address the issues of power and contradiction (see Nicolini et al., 2012). In our study, materialisation of thought in the model and its subsequent inclusion in documents for circulation as well as re-mediation in the ensuing workshop demonstrate how artefact-mediated object-oriented social learning takes place from micro-level contradictions to 'accepted' artefacts which may contain contradictions within them. As such, Kontinen

(2007) suggests that relational power is manifest in the co-construction of the activity object. This was evident in the workshop as the object 'a zero carbon zone' which had been set by the project partners with particular influence by the council's representatives, was changed to 'a low carbon zone' as a result of the participants' challenging of it. *Power over*, which was held by the project partners, shaped the design of the agenda, choice of the script (PSM), distribution of the documents (spatial planning framework) and the design of the list of invited stakeholders. However, *decentralised power* during the group modelling session was exercised to challenge the status-quo through the challenge levelled at the activity object and the development of an attenuated (more business friendly) version of it (from zero to low carbon) as well as through the inclusion of other tools for thinking, such as abstract models for 'carbon offsetting'. It would be possible to argue that *power over* was exercised for example through different levels of 'fluency' of different participants in the conceptual use of relevant models as tools for thinking and negotiating in the groups, but given that the heterogeneity in the group was more on organisational background than on socialisation in the low carbon transitions discourse, the difference in the ability to play with abstract concepts may be accepted as negligible here. The important suggestion here is that contradictions between the organisational practices of different participants led to a redefinition of the object of activity (i.e. making it shared) and the design of processes for collaboration towards the shared object (alliancing). This suggests that power is distributed in the system through the OR process, and was focalised by the activity object which was sufficiently contestable to allow its de- and re-construction as a shared activity object (Figures 7 and 8).

CONCLUSION

The paper shows how it is possible to understand PSM interventions using approaches based on AT. The case is an attempt to describe the usefulness of this approach. In particular it highlighted that OR interventions are best explained without reference to a universal method, but by viewing the relationships between the conceptual elements in activity systems as constituting activity. In this way, it is possible to investigate how PSM interventions can overcome the problems of multivoicedness, solve inherent contradictions

and utilize tensions in the activity system to develop collective artefacts (models) and practices.

The case highlighted that interventions are processes of interaction between subjects, mediated by artefacts (socio-materiality) and their success is contingent on scaffolding through methods that encourage certain behaviours (respectful listening, open conversation, asking, explaining, seeking clarification), a shared cultural understanding of affordances of artefacts in activity (common language, visualising via the taught method using the flipchart, pens, post-its), a shared object-orientation ('creating a zero carbon BTQEZ'), agreed rules and division of labour (turn taking in speech, interaction via the models, contributing to model creation, taking roles, e.g. representing their organisations).

The analysis using AT helped to theorise the micro level dynamics that characterised the collaborative group model building processes in the case study. By applying AT to study how workshop participants use mediating artefacts to grapple with the object of a 'zero carbon zone', it was possible to show how a co-constructed, shared activity system can be developed to accommodate contradictions between the subjects' activity objects.

Overall, this paper has given a glimpse of how ideas drawn from AT may be used to understand PSM interventions, applying ideas from these approaches, such as the co-creation of mediating artefacts and collective intentionality. It appears that interventions are to be understood as activity systems, oriented towards objectives, in a flux of changing circumstances and networks. AT is proposed as a tool for reflection and learning, a structure and method to interrogate practice so that learning takes place; not necessarily to lead to rules for action. In addition, a strong basis of empirical research, conducted in educational sciences, which applies AT to inform learning may support PSM method evolution. It is hoped that the use of the ideas described in the paper may contribute to an improved understanding, and possibly more robust reasons, for using PSM methods.

In terms of implications for practitioners and researchers, in various places throughout the paper, we have noted the value of socio-materialist theories sometimes for OR practitioners attempting to ensure that an intervention achieves its aims and other times for researchers attempting to develop middle-range theories for OR practice (Yearworth and White, 2014). For practitioners, this approach should help them think about the intervention process and recognize and intervene when there are problems. Specifically,

understanding that collective behaviours are emergent properties can help in planning the interventions and managing expectations.

The proposed approach takes seriously the generative nature of PSM interventions (Franco, 2013; White, 2006), and emphasizes the role of models as representations, integrating and coordinating the practice of stakeholder engagement and the significance of incoherency and dilemma for social collective learning. Behavioural dynamics are made visible through the AT notation including the subject-mediation-object unit, the cultural-historical rules, division of labour and community. The case study showed how the AT notation helps to analyse processes of re-negotiation of rules as well as the *creative* use of boundary *models (*e.g. business models) which are leading to *intended collective goals* (considering alliancing). By applying AT concepts to the empirical analysis of problem structuring work, the *process of relational co-construction* of collective and joint intention, which are precursors for collective action, may thus be understood. We have suggested that these collective intentions do not require consensus, but rather a co-construction of interdependencies between the represented organisations that becomes action-guiding through a joint focus on the activity object, which may well represent a social dilemma (e.g. climate change/a zero carbon zone), but which has sufficient drawing power for different actors to develop creative approaches for agency. As such, insights that AT provides into behaviour in problem structuring interventions may help to challenge assumptions about intervention design and develop further insight into scaffolding processes for collaborative work with collective impact.

Researchers can use such knowledge to compare interventions of similar modes in different organizations in a more systemic way and to build better mid-range theories by studying how collective action emerges in heterogeneous activity system networks through a re-construction of the structurating cultural-historical influences in the forms of rules, division of labour and community that influence how agency develops.

Finally, in terms of limitations and future research, while we have developed a basis for activity-based theories of OR interventions, there are still a number of open issues we did not address or only partially addressed. First, we briefly mentioned, but did not really address, how technology related artefacts interact with activities during an intervention

process. Second, while we illustrated our theoretical arguments with an analysis of our case study that matched our needs, we did not provide a full disclosure of the case study from start to finish, we used our case selectively to illustrate our new theoretical perspective. A full analysis of our case is likely to provide more insights and more guidelines to researchers for conducting such studies. Third, we focus on a single setting with a single method, meaning that we cannot rule out the possibility of alternative visual interactions in other settings or when multiple methods are employed. Future studies could explore the extent and significance of variations in visual interactions across multiple contexts or when particular PSMs are used. Also, since we focus on a single episode we did not examine the relative the importance of visual interactions to particular workshop outcomes. Finally, drawing on Paroutis et al (2015), a promising avenue of research would be to relate patterns of visual interactions across time particularly with multiple workshops. We have sufficient data to do this and this will be the focus of our future work.

In summary, we have made contributions and theoretical progress in filling the gap between the calls for more socio-material-based research and the theoretical foundations needed to conduct such research. We have also provided some an example of the use of AT to help others understand what they are looking for in their empirical work, but there is still much to be done. One of the best ways to continue this research stream is to conduct empirically based studies to develop such mid-range theories (Yearworth and White, 2014).

References

Andrade, A; Urquhart, C. 2010. "The affordances of actor network theory in ICT for development research." Information Technology & People 23.4; 352-374.

Andrade, A; Ekundayo. S. 2011. "Mediated Action and Network of Actors: From Ladders, Stairs and Lifts to Escalators (and Travelators)." International Journal of Actor-Network Theory and Technological Innovation (IJANTTI) 3.3. 21-34.

Andrade, A. 2012. "From Intermediary to Mediator and Vice Versa: On Agency and Intentionality of." Social Influences on Information and Communication Technology Innovations 195.

Ackermann, F., 2012. Problem structuring methods “in the Dock”: Arguing the case for Soft OR. Eur. J. Oper. Res. 219, 652–658.

Ackermann, F., Eden, C., 2011. Negotiation in Strategy Making Teams: Group Support Systems and the Process of Cognitive Change. Group Decis. Negot. 20, 293–314. doi:10.1007/s10726-008-9133-y

Bandura, A., 1990. Perceived self-efficacy in the exercise of personal agency. J. Appl. Sport Psychol. 2, 128–163. doi:10.1080/10413209008406426

Bandura, A. 2001. Social cognitive theory: An agentic perspective. Annual review of psychology 52.1 , 1-26.

Becchio, C., Bertone, C., 2004. Wittgenstein running: Neural mechanisms of collective intentionality and we-mode. Conscious. Cogn. 13, 123–133. doi:10.1016/j.concog.2003.07.002

Berkowitz, M.W., Others, A., 1986. The Development of Sociomoral Discourse.

Bertelsen, O.W., 1998. Elements of a Theory of Design Artefacts: a contribution to critical systems development research (Ph.D. Thesis). Aarhus University, Department of Information and Media Science.

Blackler, F., 1995. Knowledge, Knowledge Work and Organizations: An Overview and Interpretation. Organ. Stud. 16, 1021–1046. doi:10.1177/017084069501600605

Bratteteig, T., Ømgrim, L., 1994. Soft Dialectics–Structured Handling of Problem Situations in System Development, in: Proceedings of the Second European Conference on Information Systems. Nijenrode University, Breukelen, pp. 681–690.

Bristol City Council, 2012. Bristol Smart City Programme [WWW Document]. URL ttp://www.greendigitalcharter.eu/wp-content/uploads/2012/05/Smart-City-Bristol-Programme-April-2012-Briefing-Note.doc (accessed 11.27.14).

Callon, M. (1986). Some elements of a sociology of translation: domestication of the scallops and the fishermen of St. Brieuc Bay. In J. E. Law (Ed.), Power, action, and belief: A new sociology of knowledge. London: Routledge.

Carley, KM. 1997. Extracting team mental model through textual analysis. *Journal of Organizational Behavior*, 18: 533–558.

Chiva, R., Alegre, J., 2005. Organizational Learning and Organizational Knowledge Towards the Integration of Two Approaches. Manag. Learn. 36, 49–68.

Clark, A., 2008. Pressing the Flesh: A Tension in the Study of the Embodied, Embedded Mind?*. Philos. Phenomenol. Res. 76, 37–59. doi:10.1111/j.1933-1592.2007.00114.x

Clegg, S.R., Cunha, J.V. da, Cunha, M.P. e, 2002. Management Paradoxes: A Relational View. Hum. Relat. 55, 483–503. doi:10.1177/0018726702555001

Cobb, P., Bowers, J., 1999. Cognitive and Situated Learning Perspectives in Theory and Practice. Educ. Res. 28, 4–15. doi:10.3102/0013189X028002004

Cole, M., Engestrom, Y., Vasquez, O., 1997. Mind, Culture, and Activity: Seminal Papers from the Laboratory of Comparative Human Cognition. Cambridge University Press.

Connell, N.A.D., 2001. Evaluating Soft OR: Some Reflections on an Apparently "Unsuccessful" Implementation Using a Soft Systems Methodology (SSM) Based Approach. J. Oper. Res. Soc. 52, 150–160.

Crang, M. & Cook, I., 2007. Doing Ethnographies. London: SAGE.

Davids, K., Araújo, D., 2010. Perception of affordances in multi-scale dynamics as an alternative explanation for equivalence of analogical and inferential reasoning in animals and humans. Theory Psychol. 20, 125–134.

Davis, J., MacDonald, A., White, L., 2010. Problem-structuring methods and project management: an example of stakeholder involvement using Hierarchical Process Modelling methodology. J. Oper. Res. Soc. 61, 893–904. doi:10.1057/jors.2010.12

Eden, C., 1995. On evaluating the performance of "wide-band" GDSS's. Eur. J. Oper. Res. 81, 302–311. doi:10.1016/0377-2217(93)E0241-O

Eden, C., Ackermann, F., 2013. Making Strategy: The Journey of Strategic Management. SAGE Publications.

Emerson, R.M., 2004. Working With "Key Incidents," in: eale, C., Gobo, G., Gubrium, J. F., & Silverman, D. (Ed.), Qualitative Research Practice. Edited by Clive Seale et Al. SAGE.

Engeström, Y., 1987. Learning by expanding. Helsinki: Orienta-Konsultit.

Engestrom, Y., 1996. Interobjectivity, Ideality, and Dialectics. Mind Cult. Act. 3, 259–265. doi:10.1207/s15327884mca0304_5

Engeström, Y., 1999. Innovative learning in work teams: Analyzing cycles of knowledge creation in practice, in: Perspectives on Activity Theory, Edited by Engeström, Y., Miettinen, R., and Punamäki, R. Cambridge University Press.

Engeström, Y., 2001. Expansive learning at work: Toward an activity theoretical reconceptualization. J. Educ. Work 14, 133–156.

Engeström, Y., 2004. New forms of learning in co-configuration work. J. Workplace Learn. 16, 11–21. doi:10.1108/13665620410521477

Engeström, Y., 2005a. Developmental Work Research: Expanding Activity Theory in Practice. Lehmanns Media.

Engeström, Y., 2005b. Knotworking to Create Collaborative Intentionality Capital in Fluid Organizational Fields, in: Collaborative Capital: Creating Intangible Value, Advances in Interdisciplinary Studies of Work Teams. Emerald Group Publishing Limited, pp. 307–336.

Engeström, Y., 2008. From Teams to Knots: Activity-Theoretical Studies of Collaboration and Learning at Work. Cambridge University Press.

Engeström, Y., 2009. The Future of Activity Theory: A Rough Draft, in: Learning and Expanding with Activity Theory. Cambridge University Press.

Engeström, Y., Blackler, F., 2005. On the Life of the Object. Organization 12, 307–330. doi:10.1177/1350508405051268

Fenwick, T., 2010. "Re-thinking the "thing" Sociomaterial approaches to understanding and researching learning in work." Journal of Workplace Learning 22.1/2 (2010): 104-116.

Fenwick, T., Richard E., Sawchuk, P., 2015. Emerging approaches to educational research: Tracing the socio-material. Routledge

Franco, A., 2013. Rethinking Soft OR interventions: Models as boundary objects. Eur. J. Oper. Res. 231, 720–733. doi:10.1016/j.ejor.2013.06.033

Franco, L.A., Montibeller, G., 2010. Facilitated modelling in operational research. Eur. J. Oper. Res. 205, 489–500.

Froschauer, Ulrike. 2009. "Artefaktanalyse (Artefact analysis)." In *Handbuch Methoden der Organisationsforschung (Handbook of Methods of Organisation Research)*, edited by Stefan Kühl, Petra Strodtholz, and Andreas Taffertshofer, 326–47. VS Verlag für Sozialwissenschaften. http://link.springer.com/chapter/10.1007/978-3-531-91570-8_16.

Gibson, J.J., 1950. The implications of learning theory for social psychology., in: In J.G. Miller (Ed.), Experiments in Social Process. McGraw-Hill, New York.

Gibson, J.J., 1979. The Theory of Affordances (1979), in: The People, Place, and Space Reader Edited by Jen Jack Gieseking, William Mangold, Cindi Katz, Setha Low, Susan Saegert. Routledge.

Gigerenzer, G., 1996. On narrow norms and vague heuristics: A reply to Kahneman and Tversky. Psychol. Rev. 103, 592–596. doi:10.1037/0033-295X.103.3.592

Gigerenzer, G., 2006. Bounded and rational., in: In R.J. Stainton (Ed.) , Contemporary Debates in Cognitive Science. Blackwell, Oxford, pp. 115–133.

Goodman, E.S., 2013. Delivering Design: Performance and Materiality in Professional Interaction Design (Doctor of Philosophy in Information Management and Systems). University of California, Berkeley.

Gordon, B., Theiner, G., forthcoming. Scaffolded Joint Action as a Micro–Foundation of Organizational Learning, in: Stone, C.B., Bietti, L. (Eds.), Contextualizing Human Memory: An Interdisciplinary Approach to Understanding How Individuals and Groups Remember the Past. Psychology Press.

Greeno, J.G., 1998. The situativity of knowing, learning, and research. Am. Psychol. 53, 5–26. doi:10.1037/0003-066X.53.1.5

Hämäläinen, R.P., Luoma, J., Saarinen, E., 2013. On the importance of behavioral operational research: The case of understanding and communicating about dynamic systems. Eur. J. Oper. Res. 228, 623–634. doi:10.1016/j.ejor.2013.02.001

Harré, R., Clarke, D., DeCarlo, N., 1985. Motives and mechanisms: An introduction to the psychology of action. Methuen, London.

Hodder, I., 2012. The Interpretation of Documents and Material Culture, in: SAGE Biographical Research. SAGE.

Hogarth, R. M. 1981. Beyond discrete biases: Functional and dysfunctional aspects of judgmental heuristics. Psychological Bulletin, 90, 197-217.

Holland, D. & Cole, M. 1995. Between discourse and schema: Reformulating a cultural-historical approach to culture and mind. *Anthropology & Education Quarterly*, *26*(4), 475-489.

Jäger, S., 2012. Kritische Diskursanalyse: Eine Einführung, Auflage: 6., 6., vollständig überarbeitete Auflage. ed. Unrast, Münster, Westf.

Jewitt, C. 2012. An introduction to using video for research.

John-Steiner, V., Mahn, H., 1996. Sociocultural approaches to learning and development: A Vygotskian framework. Educ. Psychol. 31, 191–206.

Jonassen, D., Land, S., 2012. Theoretical foundations of learning environments. Routledge.

Jordan, B., Henderson, A., 1995. Interaction analysis: Foundations and practice. J. Learn. Sci. 4, 39–103.

Kanno, T., Nakata, K., Furuta, K., 2003. A method for team intention inference. Int. J. Hum.-Comput. Stud. 58, 393–413. doi:10.1016/S1071-5819(03)00011-9

Kahneman, D., Tversky, A., 1984. Choices, values, and frames. Am. Psychol. 39, 341–350. doi:10.1037/0003-066X.39.4.341

Kaptelinin, V., 1996. Activity Theory: Implications for Human-Computer Interaction, in: Context and Consciousness: Activity Theory and Human-Computer Interaction, Edited by Bonnie A. Nardi. MIT Press.

Kaptelinin, V., Nardi, B.A., 1997. Activity theory: basic concepts and applications. *CHI'97 Extended Abstracts on Human Factors in Computing Systems*. ACM

Kaptelinin, V., Nardi, B.A., 2006. Acting with Technology: Activity Theory and Interaction Design. MIT Press.

Kara, H. 2015. Creative Research Methods in the Social Sciences: A Practical Guide. Policy Press.

Keys, P., 1995. Understanding the Process of Operational Research: Collected Readings. John Wiley & Sons Ltd.

Keys, P., 1997. Approaches to understanding the process of OR: Review, critique and extension. Omega 25, 1–13. doi:10.1016/S0305-0483(96)00049-7

Kiekel, P.A., Cooke, N.J., Foltz, P.W., Shope, S.M., 2001. Automating measurement of team cognition through analysis of communication data, in: In. pp. 1382–1386.

Kontinen, T., 2007. Learning Challenges of NGOs in Development. CO-operation of Finnish NGOs in Morogoro, Tanzania. University of Helsinki,.

Kontinen, T., 2013. A Gramscian perspective on developmental work research: Contradictions, power and the role of researchers reconsidered. Outl. Crit. Pract. Stud. 14, 106–129.

Kunc, M.H., Morecroft, J.D.W., 2009. Resource-based strategies and problem structuring: using resource maps to manage resource systems. J. Oper. Res. Soc. 60, 191–199. doi:10.1057/palgrave.jors.2602551

Kuutti, K., 1996. Activity theory as a potential framework for human-computer interaction research. Context Conscious. Act. Theory Hum.-Comput. Interact. 17–44.

Latour, B., 1987. Science in action: How to follow scientists and engineers through society. Harvard Univ Pr.

Latour, B. (1992). Reassembling the social: An introduction to actor-network-theory. Oxford: Oxford University Press.

Latour, B., 1996a. On interobjectivity. Mind, culture, and activity, 3(4), 228-245.

Latour, B., 1996b. Pursuing the discussion of interobjectivity with a few friends. Mind, Culture, and Activity, 3(4), 266-269.

Lave, J., Wenger, E., 1991. Situated Learning: Legitimate Peripheral Participation. Cambridge University Press.

Law J (1992). Notes on the theory of actor-networks: ordering, strategy, and heterogeneity. Systems Pract 5: 379-393

Leontiev, A.N., 1981. “The problem of activity in psychology,” in: The Concept of Activity in Soviet Psychology, Edited by Wertsch, J. V.pp.37-71. Sharpe.

Luff, Paul, and Christian Heath.2012. Some ‘technical challenges’ of video analysis: social actions, objects, material realities and the problems of perspective Qualitative Research 12.3 (2012): 255-279.

Lynch, M., 1996. DeKanting Agency: Comments on Bruno Latour's" On Interobjectivity". Mind, Culture, and Activity, 3(4), 246-251.Menary, R., 2006. Attacking the Bounds of Cognition. Philos. Psychol. 19, 329–344. doi:10.1080/09515080600690557

Midgley, G., Cavana, R.Y., Brocklesby, J., Foote, J.L., Wood, D.R.R., Ahuriri-Driscoll, A., 2013. Towards a new framework for evaluating systemic problem structuring methods. Eur. J. Oper. Res. 229, 143–154. doi:10.1016/j.ejor.2013.01.047

Miettinen, R., 1999. The riddle of things: Activity theory and actor-network theory as approaches to studying innovations. Mind Cult. Act. 6, 170–195.

Miettinen, R., Virkkunen, J., 2005. Epistemic Objects, Artefacts and Organizational Change. Organization 12, 437–456. doi:10.1177/1350508405051279

Mingers, J., 2000. The contribution of critical realism as an underpinning philosophy for OR / MS and systems. J. Oper. Res. Soc. 51, 1256–1270.

Mingers, J., 2007. Operational Research: The Science of Better? J. Oper. Res. Soc. 58, 683–686.

Mingers, J. 2011. Soft OR comes of age-but not everywhere! Omega-International Journal of Management Science 39(6): 729-741.

Mingers, J., Rosenhead, J., 2004. Problem structuring methods in action. Eur. J. Oper. Res. 152, 530–554.

Montibeller, G., Franco, A., 2007. Decision and risk analysis for the evaluation of strategic options, in: O'Brien, F.A., Dyson, R.G. (Eds.), Supporting Strategy: Frameworks, Methods and Models. John Wiley & Sons, West Sussex, UK, pp. 251–284.

Nardi, B. A. (1996). Context and consciousness: activity theory and human-computer interaction. Mit Press.

Nicolini, D., 2009. Zooming In and Out: Studying Practices by Switching Theoretical Lenses and Trailing Connections. Organ. Stud. 30, 1391–1418. doi:10.1177/0170840609349875

Nicolini, D., Mengis, J., Swan, J., 2012. Understanding the role of objects in cross-disciplinary collaboration. Organ. Sci. 23, 612–629.

Nonaka, I., Takeuchi, H., 1995. The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press.

North, P., 2013. Knowledge exchange,"impact"and engagement: exploring low-carbon urban transitions. Geogr. J. 179, 211–220.

Nurse, A., North, P., 2013. Developing a Conceptual Framework for the Study of Low Carbon Policy at the City Level.

Orlikowski, W., 2005. Material Works: Exploring the Situated Entanglement of Technological Performativity and Human Agency. Scand. J. Inf. Syst. 17.

Ormerod, R., 2006. The History and Ideas of Pragmatism. J. Oper. Res. Soc. 57, 892–909.

Packer, M.J., Goicoechea, J., 2000. Sociocultural and constructivist theories of learning: Ontology, not just epistemology. Educ. Psychol. 35, 227–241.

Paroutis, S., Franco, L. A., & Papadopoulos, T. (2015). Visual interactions with strategy tools: producing strategic knowledge in workshops. *British Journal of Management*, *26*(S1), S48-S66.

Phillips, L.D., 1982. Requisite Decision Modelling: A Case Study. J. Oper. Res. Soc. 33, 303. doi:10.2307/2581639

Phillips, L.D., 1984. A theory of requisite decision models. Acta Psychol. (Amst.) 56, 29–48. doi:10.1016/0001-6918(84)90005-2

Pickering, A. 1993. The mangle of practice - agency and emergence in the sociology of science. *American Journal of Sociology, 99*(3), 559-589. doi: 10.1086/230316

Pickering, A. 1995. *The mangle of practice : time, agency, and science*. Chicago ; London: University of Chicago Press.

Pickering, A., 1992. Science as Practice and Culture. University of Chicago Press.

Preston, Beth. *A Philosophy of Material Culture: Action, Function, and Mind: Action, Function, and Mind*. Routledge, 2013.

Powell, W. W., & DiMaggio, P. J. (Eds.). (2012). *The new institutionalism in organizational analysis*. University of Chicago Press.

Rittel, H.W.J., Webber, M.M., 1973. Dilemmas in a general theory of planning. Policy Sci. 4, 155–169.

Rogoff, B. 2008. "Observing Sociocultural Activity on Three Planes: Participatory Appropriation, Guided Participation, and Apprenticeship." In *Pedagogy and Practice: Culture and Identities*. SAGE.

Sandberg, J., Tsoukas, H., 2011. Grasping the Logic of Practice: Theorizing Through Practical Rationality. Acad. Manage. Rev. 36, 338–360.

Schaal, S., 2009. Arbeitstätigkeit in Organisationen: Betrachtung aus Sicht der Tätigkeitstheorie, der Akteur-Netzwerk-Theorie und des boundary object [Work in organisations: studied from the point of view of activity theory, actor-network theory and the boundary object].

Schatzki, T.R., 2008. Social Practices: A Wittgensteinian Approach to Human Activity and the Social, 1 edition. ed. Cambridge University Press, New York.

Scriven, R. Video methodologies and engaging with mobilities.

Shaffer, D.W., Clinton, K.A., 2005. Why All CSL is CL: Distributed Mind and the Future of Computer Supported Collaborative Learning, in: Proceedings of Th 2005 Conference on Computer Support for Collaborative Learning: Learning 2005: The Next 10 Years!, CSCL '05. International Society of the Learning Sciences, Taipei, Taiwan, pp. 592–601.

Shaffer, D.W., Clinton, K.A., 2006. Toolforthoughts: Reexamining Thinking in the Digital Age. Mind Cult. Act. 13, 283–300.

Simon, H. A. 1955. A behavioral model of rational choice. Quarterly Journal of Economics, 69, 99-118.

Star, S.L., 1999. The Ethnography of Infrastructure. Am. Behav. Sci. 43, 377–391. doi:10.1177/00027649921955326

STEEP, 2011. Systems Thinking for Comprehensive City Efficient Energy Planning (Proposal), STEEP PROJECT (314277) - Systems Thinking for Comprehensive City Efficient Energy Planning.

Sterman, J.D., 1989. Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment. Manag. Sci. 35, 321–339. doi:10.1287/mnsc.35.3.321

Sunstein, C.R., Thaler, R.H., 2003. Libertarian Paternalism Is Not An Oxymoron (SSRN Scholarly Paper No. ID 405940). Social Science Research Network, Rochester, NY.

Strübing, Jörg. Pragmatistische Wissenschafts-und Technikforschung: Theorie und Methode. (Pragmatist Science- and Technology Studies: Theory and Method) Campus Verlag, 2005.

Taket, A., White, L., 1994. Doing community operational research with multicultural groups. Omega 22, 579–588. doi:10.1016/0305-0483(94)90049-3

Taket, A., White, L., 2000a. Partnership & Participation. John Wiley & Sons.

Taket, A., White, L., 2000b. Assessment of health service systems: a case study of metamodelling to explore options for future health service provision. Int. J. Serv. Technol. Manag. 1, 320–331.

Tomasello, M., 2009. Why We Cooperate. MIT Press.

Tsoukas, H., 2003. Do we really understand tacit knowledge. Blackwell Handb. Organ. Learn. Knowl. Manag. 410–427.

Tuomela, R., 1995. The Importance of Us: A Philosophical Study of Basic Social Notions. Stanford University Press.

Tuomela, R., 2000. Collective and joint intention. Mind & Society 1.2, 39-69.

Tuomela, R., 2005. I-mode and We-mode Shared Intentionality, in: Debate on "Shared Intentionality", Chaired by Livia Colle & Christina Becchio (23.07.2005). Presented at the XXVII Annual Conference of the Cognitive Science Society.

Tuomela, R., Miller, K., 2009. Einführung, in: Schmid, H.-B., Schweikard, D.P. (Eds.), Kollektive Intentionalität: Eine Debatte über die Grundlagen des Sozialen. Suhrkamp Verlag Gmbh, Frankfurt am Main.

Tuomela, R., 2013. Social Ontology: Collective Intentionality and Group Agents. OUP USA.

Turner, J., 2011, "Who Killed the Primary Care Strategy?, PhD Thesis, University of Stirling

Traweek, S. 1992. "Border crossings: narrative strategies in science studies and among physicists in Tsukuba Science City, Japan." Science as practice and culture, pp.429-465.

Van Lier, L., 2000. 11 From input to affordance: Social-interactive learning from an ecological perspective. Sociocult. Theory Second Lang. Learn. 245.

Vennix, Jac AM, and Jac Vennix. *Group model building: Facilitating team learning using system dynamics*. Vol. 2001. Chichester: Wiley, 1996.

Vygotsky, L.S., 1981. The instrumental method in psychology., in: In J. V. Wertsch (Ed.), The Concept of Activity in Soviet Psychology (pp.134-144). Sharpe, Armonk, NY.

Wartofsky, M.W., 1979. Models: Representation and the Scientific Understanding. Springer Science & Business Media.

Yearworth, M., White, L., 2014. The non-codified use of problem structuring methods and the need for a generic constitutive definition. Eur. J. Oper. Res. 237, 932–945.

White, L., 2006. Evaluating problem-structuring methods: developing an approach to show the value and effectiveness of PSMs. J. Oper. Res. Soc. 57, 842–855.

White, L., 2009. Understanding problem structuring methods interventions. Eur. J. Oper. Res. 199, 823–833.

White, L., 2014. Behavioural Issues in PSMs [WWW Document]. IFORS Conf. Present. URL http://www.ifors2014.org/files2/program-ifors2014.pdf

White, L., Taket, A., 2000. Exploring the use of narrative analysis as an operational research method: A case study in voluntary sector evaluation. J. Oper. Res. Soc. 51, 700–711. doi:10.1057/palgrave.jors.2600959

Whittle, A., Spicer, A., 2008. Is Actor Network Theory Critique? Organ. Stud. 29, 611–629.

Figures and Tables

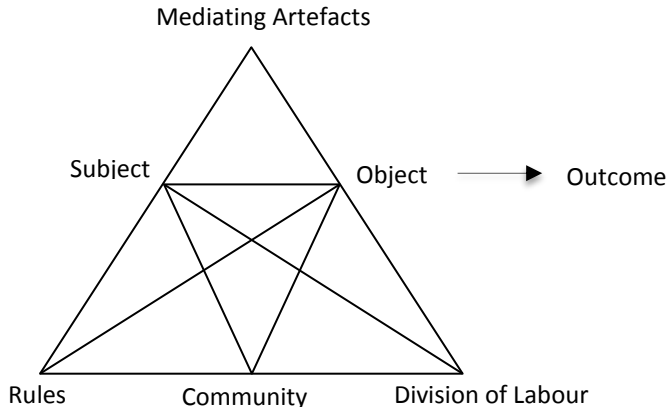


Figure 1 Activity System Concepts (Engeström, 1987)

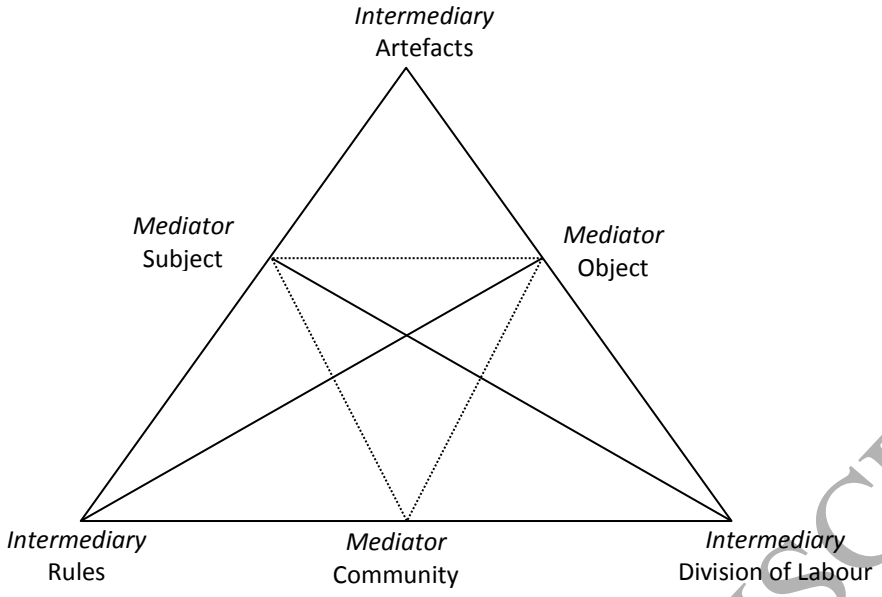


Figure 2 Activity systems network: Conceptual components of collective behaviour (Engeström, 1999)

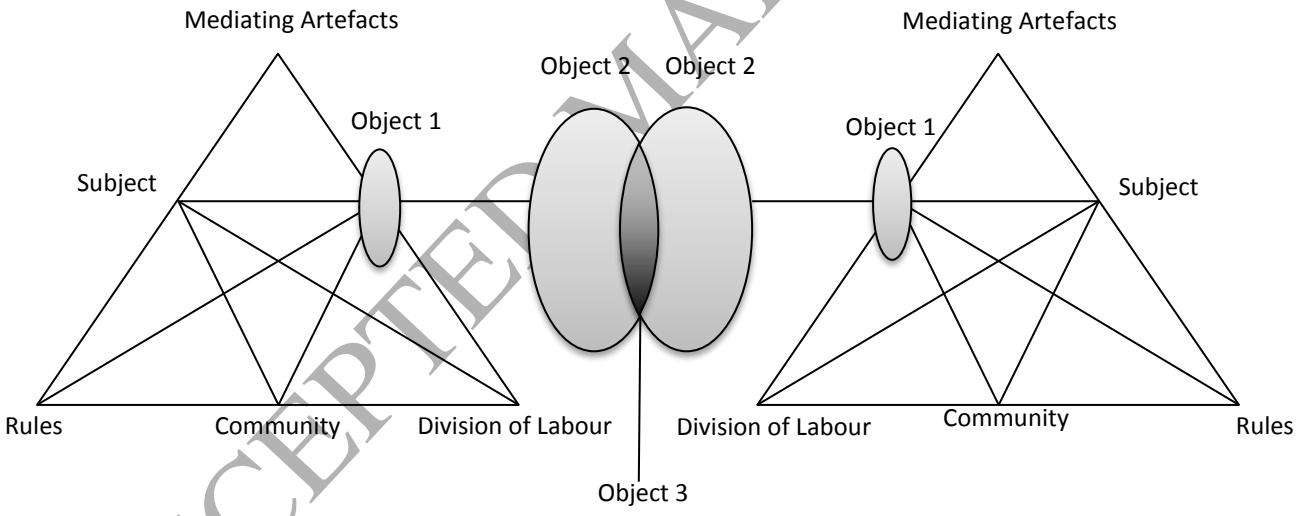


Figure 3 - Possible relationship between ANT and AT concepts (adapted and translated from (Schaal, 2009))

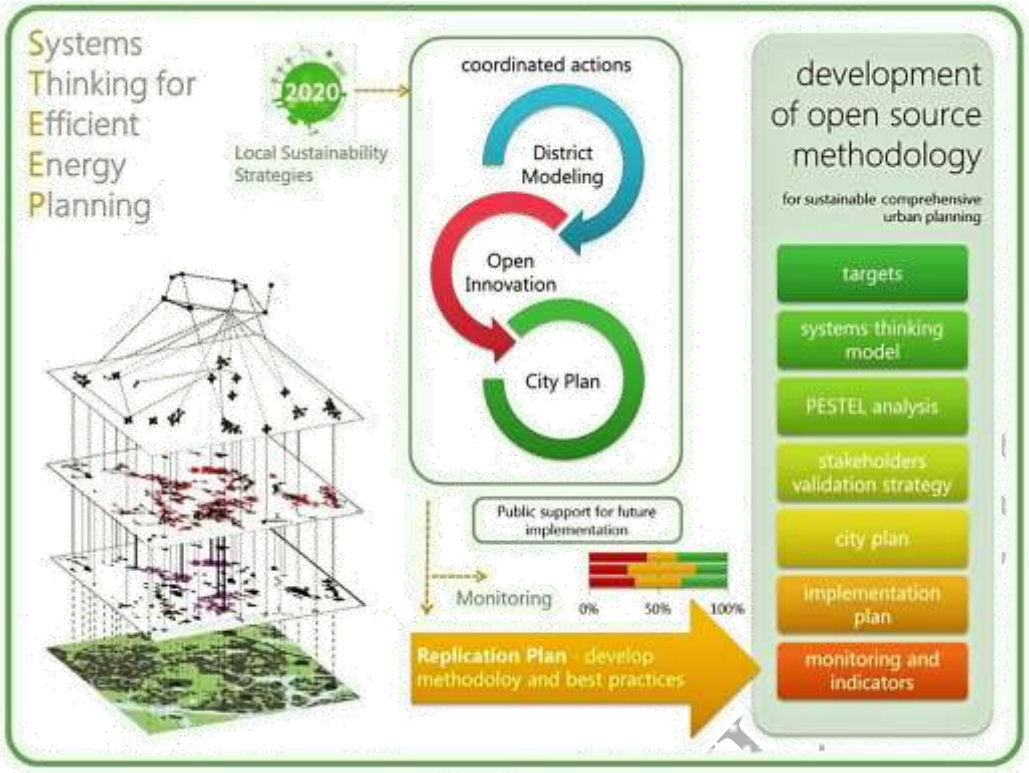


Figure 4 - STEEP project aims (STEEP, 2011)

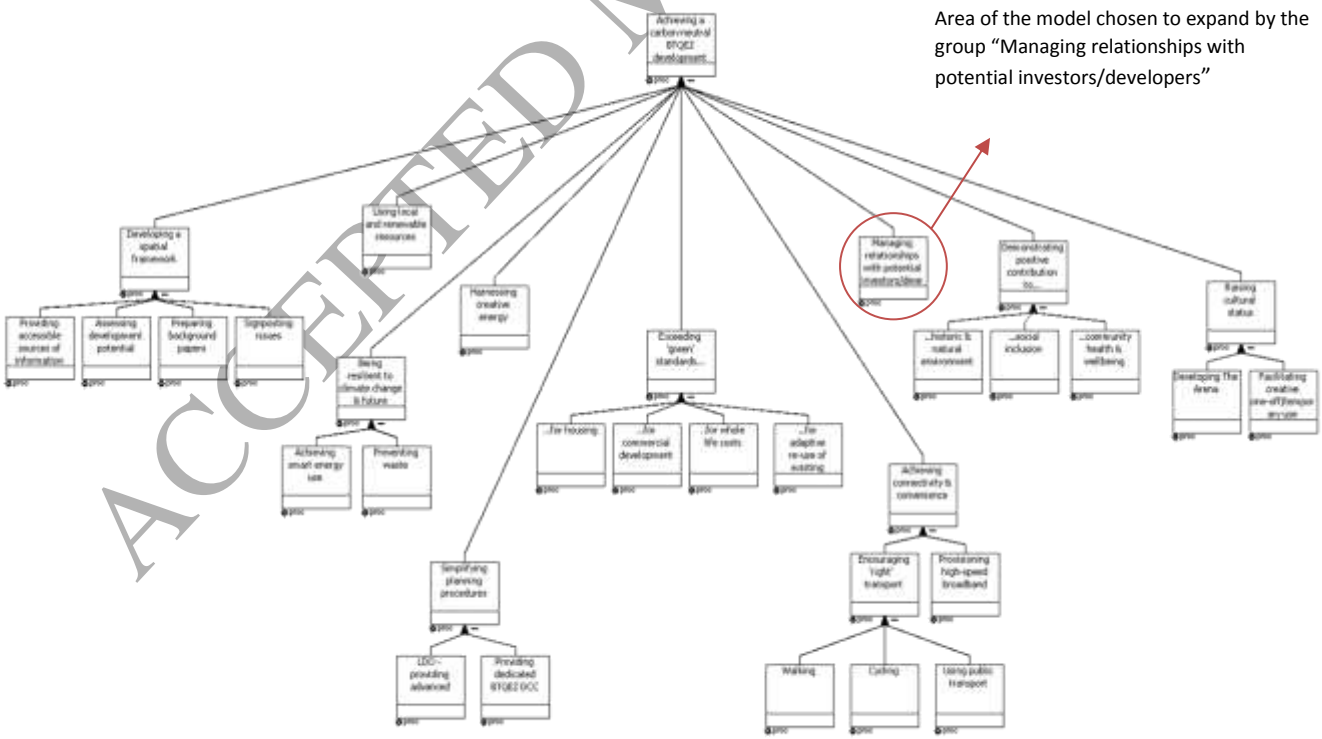


Figure 5 - Model provided by the facilitator as a starting point

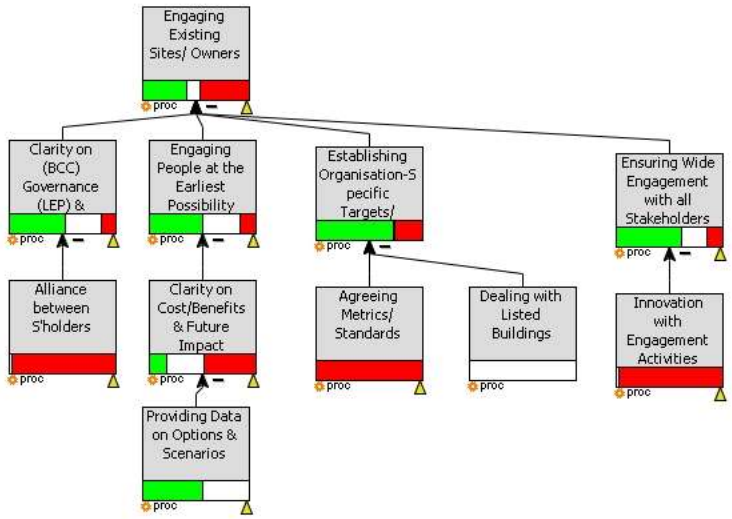


Figure 6 - Model segment developed by the group during the workshop

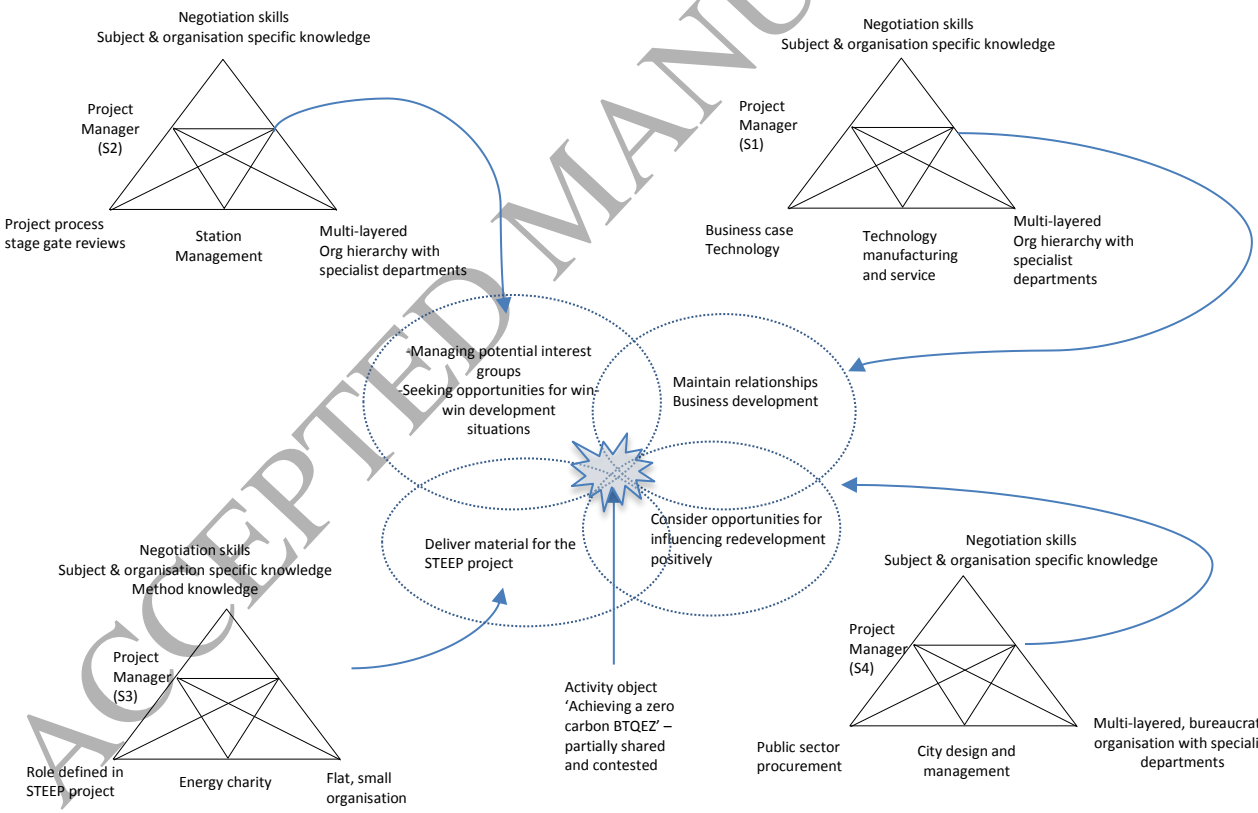


Figure 7 - Activity systems of group participants at the start of the exercise

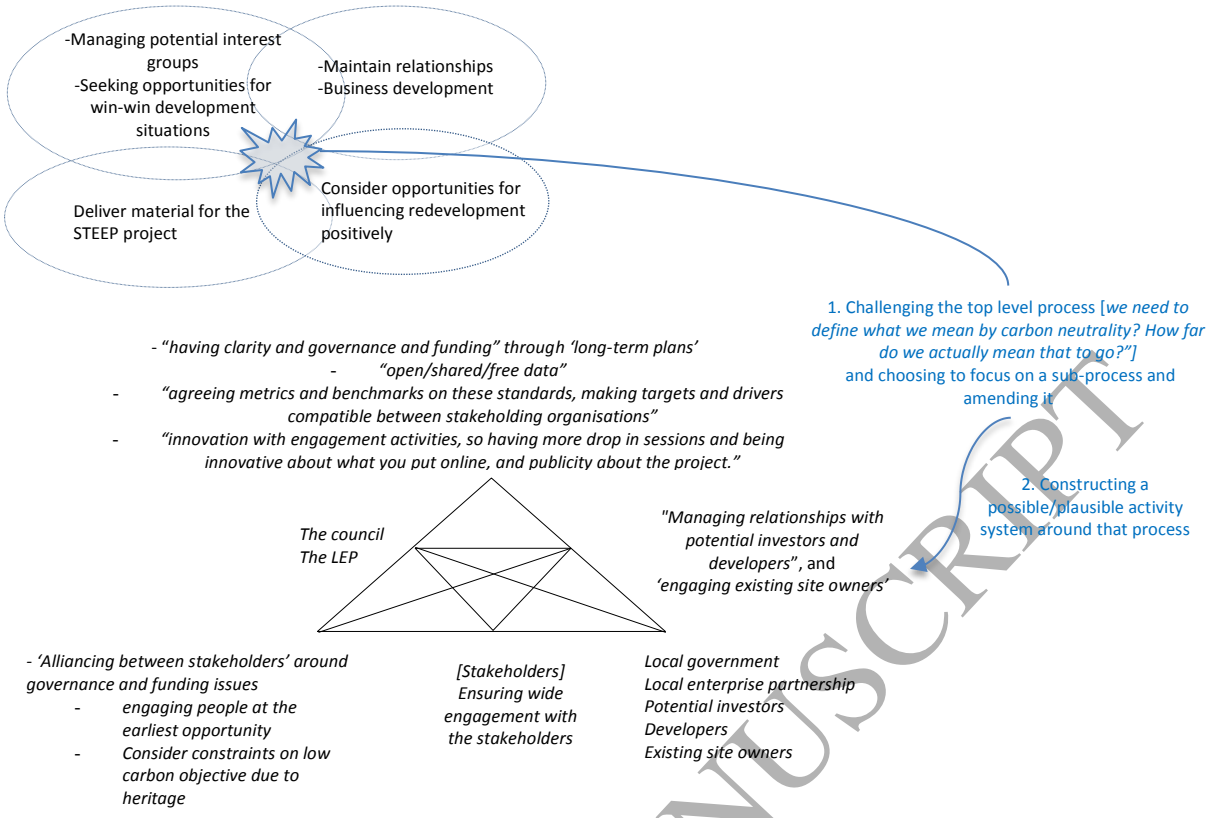


Figure 8 - Representing the group feedback in AT triangle format

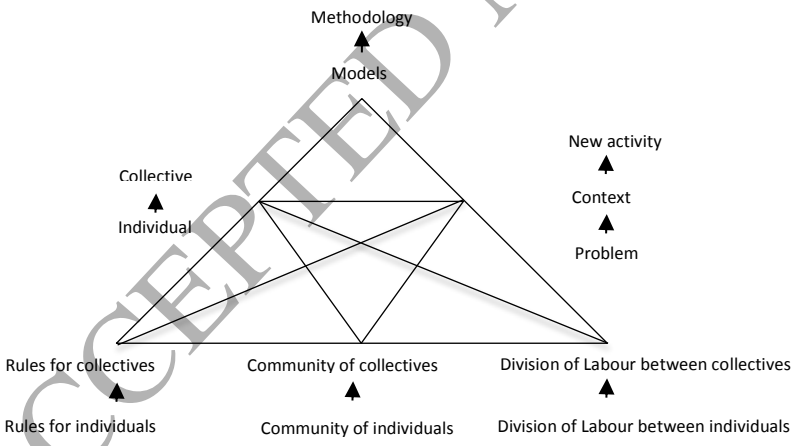


Figure 9 – The structure of learning activity (Engeström, 1987)

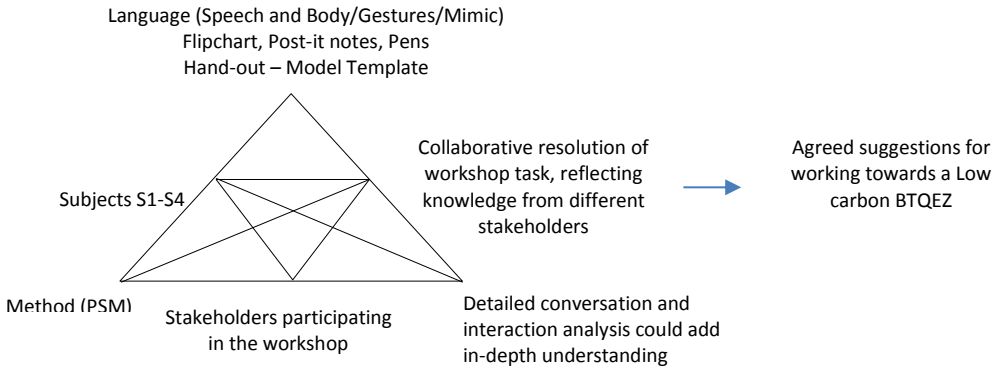


Figure 10 - Simplified PSM group model building description for one group

Table 1 Distinction between activity objects and tools/instruments in activity theory (Kuutti, 1996)

	Mediating Artefacts (Tool, Instrument)	**Activity Objects**
Activity (motive)	Enables the automation of a new routine or construction of a new tool	Enables something to become a common object (*Gegenstand, runaway objects, collective inscribed objectives, motives)*
Action (goal)	Supports transformative and manipulative actions Makes tools and procedures visible and comprehensible	Makes an object manipulable
Operation (conditions)	Automates routines	Provides data about an object

Appendix 1. Table 2: Comparison between key concepts in AT, ANT and Boundary objects (Adapted and translated from Schaal (2009, p.38ff).

Dimension	Activity Theory	Actor-Network-Theory	Boundary Objects
Object	*A* collectively shaped motive that connects the participants in an activity system	Collectively negotiated goals in a network	Local object which can be abstracted sufficiently to take on a new specific Gestalt in a different activity system
Subject	An individual, a group or an organisation may be chosen as the plane of reference	An actant (human, or non-human, such as an organisation, or a technical or symbolic artefact) that can associate or dissociate with other actants	Subjects in cooperating activity systems Actors in connected networks
Instruments	All technical and symbolic instruments that mediate between subject and object	Everything that is used to translate, i.e. for the negotiation of interests	Repositories and standardised forms
Rules	Implicitly shared and historically developed	Roles in the network that were formed through translations and negotiations between actors	n/a
Community	The subject and the community of individuals share the same object	All actors or actants of the network, including non-human entities	All actors or participants of cooperating networks or activity systems that are connected through boundary object(s)
Division of labour	Vertical and horizontal division of labour	The roles of actors in the network are created through translations	is a pre-requisite for cooperation between different networks/activity systems
Contradictions	Structural, historically grown tensions trigger change	Expressed through the degree of convergence and irreversibility of the actor-network	n/a
Learning	Expansive cycles (with internalisation and externalisation processes) that the entire activity system goes through when contradictions become salient	n/a	n/a

ppendix 2

Appendix 2 – Indicators of socio-material affordances in a problem structuring intervention: Indicative Analysis of a 2min:6sec segment

The aim of this section is to illustrate how the use of video assisted the analysis of the participant's non-verbal evidence of the perceived affordances of the environmental and social context that influence the likely efficacy of group model building interventions. The video data collected enabled a number of investigations relevant to this issue. In order to explore the prevalence of relevant non-verbal behaviours, a coding scheme was developed. Table 1 shows the categories for the coding.

Developing a coding scheme based on activity theory

Dialogism

In order to develop a coding scheme that considers some of the key aspects of activity theory, it is important to not focus on individuals but rather on interactions and in particular how each utterance relates to the next and the previous.

Socio-materiality

Another key concept in activity theory, when studying model mediated activity, is that any artefact is at one *ideal* (conceptual) and material. This has two consequences for the analysis of video data. Firstly, *significance* is created through the performance (externalisation) of speech (verbal and non-verbal), necessitating a multi-modal analysis scheme. Secondly, the temporal extension of praxis means that an ideational planning process (e.g. the design of a low carbon zone) is material in the sense that it is part of creating the physical low carbon zone later on. Discourse analysis is thus suitable to re-construct the historically imbued *significance* of concepts as well as their use for the regulation of future activity. In addition, given our research interest in *collective social learning*, a coding scheme based on social psychology is necessary.

Coding Scheme - how bodily aspects contribute to the achievement of cooperation despite the absence of consensus

- **Coding the ideal and material *in situ***

Considering the *multiple modalities* employed in the process of model-mediated problem structuring, the video analysis shows how gestures, gazes, the positions of bodies, the use of tools for pointing (e.g. pens) and making thinking explicit (the flipchart with post it notes) may add to our understanding. In addition to analysing recorded speech (in the main body of the paper), this frame by frame analysis draws attention to the embodied and enacted processes that occur

  - **Model interaction**: integrating [MII], organising [MIO], connecting [MIC], retrieving [MIR]
  - **Utterances**[1]**:** Indexical [SPI], Elliptical [SPE] and Projective [SPP]

- **Coding ideal temporally extended properties [AT concepts]**

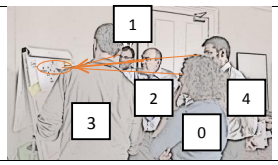
First-order properties	Second-order properties (temporally extended relational agencies)	System view
Subject [S]	Subject-artefact-object [SAO] Subject-Artefacts-Division of Labour [SAD] Artefacts-rules-objects [ARO] Object-Division of Labour-Community [ODC]	Activity system • Contradictions [CD] • Historicity [HS]
Artefact [A]		

[1] Stahl, G. (2004). Building collaborative knowing. In *What we know about CSCL*(pp. 53-85). Springer Netherlands

Object [O]		• Multivoicedness [MV] • Expansive learning [EL]
Rules [R]	Subject-rules-community [SRC] Subject-rules-object [SRO] Subject-rules-division of labour [SRD]	
Community [C]	Subject-community-object [SCO] Subject-artefacts-community [SAC] Community –artefact-object [CAO]	
Division of Labour [D]	Subject-community-division of labour [SCD] Object-rules-division of labour [ORD] Community-object-division of labour [COD]	

Table 1 Coding Activity Theory properties

- **Coding collective social learning**
    - **Speech:** self-regulation [CLSE]; other-regulation[CLOR]; shared-regulation[CLSH] ; group planning[CLGP], monitoring [CLMO] and regulation [CLRE] of a joint activity
    - **Observational learning:** attention [OLAT]; motivation [OLMO]

Video frames			
Time	11:22 (Frame 1 –Episode start)	11:23 (Frame 2)	11:25 (Frame 3)
Interaction			
Audio	*Part of it is also balancing …spent…*	*so that's about resourcing/alliancing…*	*what you're able to do with what they're able to do…*
Visible movements Observational learning	By using his pen to point at an issue in the template model, S2 focuses the gaze of the other participants [OLAT] [OLMO]	S1s head is tilt towards S4s response, suggesting careful listening [OLAT]	S2 establishes a physical connection in support of verbal statement with S3 with his extended arm [OLAT] [OLMO]
Model interaction	S2 points at a process box in the model to raise a problem with the representation in the model [MIR]	S2 creates a physical connection between the model and S4 by keeping the arm extended whilst shifting the body/gaze towards S4.	
Utterance	[SPE] ref: the low carbon zone	[SPP]	[SPI] : implied: resources
Activity theory concept	Subject - Rules (accounting/business continuity) –object [SRO]	Object-Rules (contractual relationships)-division of labour [ORD]	Community –object -Division of Labour [COD]
Collective social learning	[CLSE]	[CLGP]	[CLOR]
Free coding (themes)	*Problematisation (framing a problem):* Individual 'subjects' versus synergistic 'community' approaches to low carbon development		

Video frames			
Time	11:51 (Frame 4)	11:58 (Frame 5)	12:01 (Frame 6)
Interaction			
Audio	*… if I've got a 10% carbon reduction target, and you're aiming for 20… how do we align our targets?*	-	*And also how do you align that with the targets that investors have?*
Visible movements Observational learning	S2s hand waiving iteratively towards self and other participant [OLAT] [OLMO]	S1 nodding, S2 turning head towards him	S1 speaking, head tilted towards S2
Model interaction	-	-	-
Utterance	[SPP]	-	[SPP] *Dialogue turn 1 (agree and add)*
Activity theory concept	Subject (organisation) -mediating artefact (targets)-object (lower carbon) [SAO]	-	Community-object -Division of labour [COD]
Collective social learning	[CLSH]	-	[CLRE]
Free coding (themes)	Diverging organisational targets *inside the 'community'*	-	Diverging targets *between* organisations (division of labour)

Video frames			
Time	12:05 (Frame 7)	12:22 (Frame 8)	12:26 (Frame 9)
Interaction			
Audio	*And also how do you align them with the financial requirements?*	*And also.. we're talking here about a long term process.. most companies live hand to mouth, and the only thing they worry about it the financial statement at the end of the year, because that means that we've got a job next year.*	*But we'll be looking to develop the Enterprise Zone not just with small companies*
Visible movements Observational learning	Gaze focused following S1s movement [OLAT]	S3 moves out of the camera frame (he is standing behind S0 and is listening) S2 – money counting gesture (cash flow issues SME)	S4 shifting body slightly away from S2 whilst listening, lifting eyebrows (*preparing disagreeing statement)*
Model interaction	S1 pointing at the model with the pen, to highlight another related process that is part of the problem [MIC]	-	All looking at the model whilst listening [MIC]
Utterance	[SPP]	[SPE] *implied:* long payback horizons of low carbon technology & the presence of SME *Dialogue turn 2 (reframing the issue)*	[SPP] [SPE]
Activity theory concept	Rules (financial requirements) [R]	Business models (mediating between subject (people doing business) and object (sustainable value) [CAO]	Business models (SME/large companies) [A]
Collective social learning	[CLGP][CLSH]	[CLSE]	[CLOR]
Free coding (themes)	Financing and funding are an issue	Long term versus short term thinking associated with small versus bigger companies; small companies are 'the problem'?	

Video frames			
Time	12:26 (Frame 10)	(Frame 11)	13:06 (Frame 12)
Interaction			
Audio	*But even the big ones…*	*…are you saying….* *…There is an aspiration of a carbon neutral development, which isn't bought into necessarily…*	*So the question is.. how exactly would you overcome that?*
Visible movements Observational learning	S2 turns head towards S4	S4 shrugs, eyebrows up&down	Gaze follows S0s arm/pointing finger [OLAT]
Model interaction	S0 reading a post-it note [MIR]		S0 bringing the model back into structure the conversation by *pointing at post-it* "Engaging people at the earliest opportunity" [MII]
Utterance	[SPE]	[SPP]	[SPP]
Activity theory concept	Community [C]; Division of Labour [D]	*Tension*	*Tension*
Collective social learning	[CLOR]	[≠CLSH][≠CLRE]	[≠CLSH][≠CLRE]
Free coding (themes)	There's an issue about a lack of shared understanding amongst businesses and value attributed to a zero carbon zone		

Video frames			
Time	13:12 (Frame 13)	13:24 (Frame 14)	13:28 (Frame 15)
Interaction			
Audio	*S0: You know the disconnect, the gulf between those participating in the development of the zone?* *S1: I think that you will have a mix of smaller and larger companies, you can't just…*	*you have to have innovation as well, so somehow having the engagement too is important…*	*the small companies are riskier with innovation, because they can … and also the University has links*
Visible movements Observational learning	S0 gesture: hands not meeting/different levels	body remaining open towards S0, but gaze also towards S4 [OLAT]	mirror hand gesture: *alignment* (see Frame 13)
Model interaction	-	Pointing at the model, [MIC]	-
Utterance	[SPP] [SPE] *implied:* how innovation works-diversity required	[SPP]	[SPP]
Activity theory concept	Rules - Division of labour – community	*Shared* sub-objective emerging [potential for EL]	
Collective social learning	[CLGP]	[CLSH]	[CLRE]
Free coding (themes)	In order to have innovation emerging from the zone, a mix of small and big companies will need to exist there (*so developing a low carbon zone only with big companies is not an option)*		

Video frames			
Time	13:43 (Frame 16)	13:44 (Frame 17)	13:46 (Frame 18)
Interaction			
Audio	-	-	*So it's engaging all the different groups in the task*
Visible movements Observational learning	Check post-it is ok (glance): All leaning in towards the model (is this what we said?)	-	Head movement/gaze back to group
Model interaction	S3 adding post it note (text on post-it *"Establishing organisational-specific targets/drivers &Aligning with TQEZ Goals")* [MiC]	S1 points to model to confirm importance [MIC]	whilst S1 continues to talk, S3 is drawing link line between the new and previous post-it [MIC] [MIO]
Utterance	-	-	[SPP]
Activity theory concept	Division of labour – subject – artefact [SAD]	-	Community-Artefact-Object [CAO]
Collective social learning	[CLGP]	-	[CLGP]
Free coding (themes)	Engagement of different types of businesses, amongst companies of all sizes and the local authority/land owners/developers (i.e. the organisations represented by participants + extras)		