Integrating Action Research and System Dynamics: Towards a Generic Process Design for Participative Modelling

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Abstract

The process of building system dynamics models ranges from linear iterative phases to the circular iterative phases. However, while all these process designs are well known and explicit to system dynamics modellers, they are not comprehensive for participative modelling involving clients/participants without prior modelling knowledge. This paper presents a detailed modelling process design of six phases from the prevalent system dynamics modelling literature. By clearly showing activities and outcomes of each phase, the paper posits that the purpose and benefits of participative modelling are entailed within the phases and not necessarily by the outcomes only. A new phase called action planning, derived from action research process is used to emphasise clients' contribution in participative modelling. The interplay of the six phases during modelling results into three cycles namely; problem articulation cycle, modelling proficiency cycle, and solution refinement cycle, all of which address the diversity and legitimacy of contributions by all parties.

1. Introduction

Recent focus of participative system dynamics modelling has been on group facilitation skills and process [14, 34], organisational learning [24, 27], alignment of mental models of decision-makers [26, 16], and creating consensus [26, 27]. Less attention however, has been on the details of the modelling process itself especially with regard to new modellers. Whereas the use of scripts in GMB [23, 27] is one such detailed modelling process framework, Luna-Reyes and colleagues [27, p. 315] add that documenting and reflecting about different approaches is without a doubt an important step towards accumulation of replicable knowledge in GMB. In this context, by integrating elements of AR into SD, this research focuses not on developing a new method but adding necessary details to participative system dynamics modelling process. In other words, by extending the prevalent SD modelling process [35] into a detailed process design of six iterative phases, each with explicit outcomes, this research demonstrates that integrating AR into SD yields comprehensive process modelling phases in which the purpose and benefits of modelling are entailed within the phases and not only through the outcome of modelling (cf. [36]). This argument is explored further in later sections of this paper.

The pioneering article on integration of AR and SD by Scholl [33] outlines several potential areas for the integrated research design. While Scholl acknowledges that these methods belong to separate continuums of research paradigm, i.e., SD on the quantitative side while AR on the qualitative side, he maintains that they both address ill-defined or messy problems and hence can complement each other. Narrowing down to AR, Checkland [1] points out that the most unique aspect of action research is in its iterative process of problem diagnosis, action intervention, and reflective learning by the researcher and participants. On the other hand, a SD project starts from a problem to be solved or an undesirable behaviour that is to be corrected or avoided [3]. This first step taps the wealth of information that people possess in their heads. The mental databases are a rich source of information about a system because people know the structure of a system, and the policies that guide decisions in their minds. Basing on these and other concepts about AR and SD, Scholl [33] adds that group model building (GMB) - also labelled as "client-centred system dynamics modelling" [23] brings system dynamics in close vicinity of AR.

Since participative modelling approach involves people with a wide variety of view-points [15, 37], concerns over commitment to modelling process, reaching consensus by the team, control of the team, and evaluation of outcomes of the intervention are challenging. These challenges can be mitigated if the modelling process as suggested in this research designed with consideration of three issues:

1. The aim of research. Research aim should be stated upfront even if it represents only a broad

theme for the study that requires refinement overtime.

2. Research process design. The research process is the sequence of steps by which research is conducted [38]. Therefore methodological details such as: the role of the researcher and participant or stakeholder, the process of problem diagnosis, intervention planning, stakeholder management, and the extent of reflection and learning intended, must be explicit.

3. Criteria of evaluation of research impact. Two level evaluations may be needed in participative modelling: first, on the basis of research aim and secondly, on basis of intended learning by the participants and modellers.

1.1. Justification

By all measures, the question as to whether AR and SD can benefit from each other when combined has been meticulously addressed by Scholl [33]. In addition, Scholl focuses on a number of similar topics including: descriptions of SD approach and AR methodology, commonalities and differences of AR and SD in dealing with messy problems, potential areas for integrated research designs, and potential benefits of such integrated designs over non-integrated designs. In this paper we extend this line of argument further by developing an integrated research process design for participative system dynamics modelling. The rationale is that the methodological details are clearly articulated thereby facilitating the modellers and participants with criteria on how to represent the external policy environment under investigation while maintaining relevance to knowledge development and practice.

Although the modelling process developed is comparable with those in the classical SD literature [5, 6, 35], the contribution in our case, lies in merging AR concepts and more specifically the dual aim theorisation (focus on the implementation of planned changes as well as knowledge development [38]) into the phases of model building. As a result, a new phase (action planning) is espoused and relevant details added to modelling process design. In addition, the modelling process becomes easier for participants to follow thereby increasing their contribution to model development while simultaneously improving their proficiency in modelling. Furthermore, whatever the scope of participative modelling intervention, the modeller serves two different "masters", namely; the solution beneficiaries or clients and the research community as a whole. Therefore, a modelling process that concurrently enhances service to these two "masters" as given in this paper is certainly relevant for generating replicable knowledge.

In the remaining sections of this paper, first, a brief overview and definition of key concepts is given. Next, the model building process versus participant involvement is explored and subsequently; the participative modelling process design is discussed. Thereafter, a case study is presented and preliminary results discussed. Finally, a concluding discussion is made and areas of further research highlighted. In order to reconcile the difference in descriptive personalities and concepts at the interface of AR and SD, clients, stakeholders, and participants are synonymous throughout this paper. Similarly, researcher and modeller are also synonymous. Lastly, participative modelling specifically implies participative system dynamics modelling.

2. Definition and overview of key concepts

The key concepts considered in this section are system dynamics, action research and participative modelling.

2.1. System Dynamics

System dynamics is a computer-aided approach for analysing and solving complex problems through policy design and analysis. The problems addressed by SD are based on the premise that the structure of a system, that is, the way essential system components are connected, generates its behaviour [35]. If dynamic behaviour arises from feedback within the system, finding effective policy interventions requires understanding system structure. Once a model is built, it can be used to simulate the effect of proposed actions on the problem and the system as a whole. As Forrester [4] notes, this kind of tool is necessary because, while people are good at observing the local structure of a system, they are not good at predicting how complex, interdependent systems will behave. In addition, Maani and Cavana [8] point out the advantages of SD modelling including:

- The use of causal loop and stock and flow diagrams which show the nature and direction of relationships within the system being modelled thus enabling a deeper understanding of the system.
- Verification of decision rules that are formulated for simulations as opposed to being specified as constants thus incorporating feedback effects of past reaction
- Dealing with both linear and non-linear relationships
- Using physical and information delays in modelling
- Modelling soft behavioural relationships for which adequate statistical data may not be available.

These advantages summarise issues of concern to SD model construction as well as the types of information needed in modelling, and hence underpin the modelling process design in this paper.

2.2. Action Research

From information systems perspective and organisational change research, AR offers many positive features for researchers interested in establishing the interplay between humans, technology, information, and socio-cultural contexts, since it enjoins research and practice [28, 39]. Several streams or types of AR are available to address such broader problem domain. One may adopt the action research stream that focuses on changing practice, the action science stream for conflict resolution, the participatory action research stream for participant collaboration, or the action learning stream through experiential learning [30, 29]. Regardless of the stream chosen, the design and reporting of the study must be consistent with the way it is intended. Grundy ([18] as cited by [33]) emphasises that AR projects take a "social practice, regarding it as susceptible to improvement," proceed "through a spiral of cycles" of action and reflection, and involve "those responsible for the practice in each of the moments of activity … maintaining collaborative control of the process". In the context of this paper, the participatory AR stream is adopted.

The participatory AR stream involves practitioners as both subjects and co-researchers, giving equal dependency over the definition of the problem, delineation of actions to be taken, and interpretation of results. In Grundy's words, while technical action research seeks to improve practice through the practical skills of the participants, participatory AR seeks to improve practice through application of wisdom of participants. Detailed account of AR methodology is ubiquitous in literature and will not be repeated here. However, the four major characteristics of participatory AR as summarised from the literature are worth reflecting on in the context of this research. These include:

- That AR seeks to improve practice through application of wisdom of participants. The participants set their own research agenda, collecting and analysing the data, and controlling overuse of the findings [18, 38].
- That AR simultaneously assists in practical problem solving and expands scientific knowledge. This goal extends into two important process characteristics: First, there are highly interpretive assumptions being made about observation; second, the researcher intervenes in the problem setting [20].
- That Action research is performed collaboratively and enhances the competencies of the respective actors. Enhanced competencies (an inevitable result of collaboration) are relative to the previous competencies of the researchers and subjects, and the degree to which this is a goal, and its balance between the actors, will depend upon the setting [20].
- That AR is primarily applicable for improving a problematic or social situation [33].

2.3. Participative modelling

From the SD literature, participative modelling is primarily described in terms of GMB and Modelling for Learning, and is generally positioned in modelling process as part of management discussions [15, p.4]. In addition to GMB, Rouwette [13] compares and contrasts five participative system dynamics approaches. On the other hand, synonymous participative approaches such as: targeted participative modelling [37] and participative business modelling [32] are equally anchored on SD. By combining several prolific views of participative modelling in the context of SD, we find that participative modelling implies intensive practitioners/clients' participation, rigorous analysis, and extensive system dynamics model construction, aiming to find effective policy interventions while improving competency levels of clients in dealing with their practical problems (cf., [13, 15, 32, 37]).

3. Model building process versus participant involvement

The system dynamics modelling process in general involves four to seven phases. Luna-Reyes and Andersen [5] have made a conceptual summary of these processes across five selected representatives of the classical literature into four iterative phases. These include: 1) problem definition and system conceptualisation, 2) model formulation, 3) model testing, 4) policy formulation and model use. Snabe [37] adds that these phases are concordant with participative modelling.

The phases of model building that are supported by direct client involvement in participative system dynamics modelling have been explicitly discussed by Rouwette [13]. This research has no intention of extending Rouwette's discussion as such, but merely proposing that client participation in modelling can be enhanced through detailed model process design in which the purpose and benefits of modelling are tied to the phases of modelling process and not as a final outcome of modelling. Doing so facilitates the clients to realisation that the final model may ensue from a number of iterative modules (evolving models) and so does modelling proficiency. This view is supported by Scholl [33] who maintains that practitioners or clients can benefit through learning from SD researchers how to express aspects of the problem in feedback structures and modelling terms, such that as modelling proficiency among practitioners increases, the SD researcher's educator role decreases, and the project progresses towards action planning and action taking.

Forrester [3, p.253] notes that defining the problem and conceptualising the system is not only the most critical part of the modelling process, it is also the most difficult one. Indeed failure to define the problem may lead to what Luna-Reyes and Andersen [5] call the "gap between problem modelled and the model of the problem". While these challenges are arguably overcome in participative modelling [15, 16, 27] on the premise that problem owners in this case clients are involved in modelling, the other issues in managing client groups, e.g., group facilitation skills and attitudes, overlapping client schedules and hence low commitment, may prevent active involvement of clients throughout the modelling process. By espousing the problem articulation cycle and modelling proficiency cycle in the current modelling process design, the management of clients is approached through emphasis that both modellers and clients are contributors as well as apprentices, i.e., in the problem articulation cycle, clients are mainly contributors while modellers are more of apprentices, yet the reverse is depicted in the modelling proficiency cycle.

4. Participative modelling process design

Regardless of the intervention situation, the main steps of modelling process itself remain the same [37]. The modelling process described (or simply, integrated modelling design) is comparable with those in the classical literature [5, 6, 35] as well as the participative modelling approaches [15, 25]. The difference, however, lies in the details of the process that is easier for the participants to follow, thereby increasing their contribution to and benefits from, modelling. The integrated modelling design is thus underpinned by the following characteristics:

- Explicit outcome(s) for every phase
- Evaluation at every phase as basis for advancement to the next phase
- Explicit cycles/loops during modelling. The dynamics of mandatory and optional steps during modelling results into these loops.
- Differential roles of the team are tied both to every phase and to the individual member of the team such that control over the team and respective stages is concurrent
- Modelling exercise ends with implementation of recommended policies

Therefore, prior to modelling intervention, the team comprising of modellers and stakeholders/participants must clearly understand the whole modelling process. In other words, the modeller's prime task as facilitator and process coach is to ensure that the modelling process is not only followed during the intervention, but understood by the team right from the start. This task is simplified by the modelling process design in Figure 1.

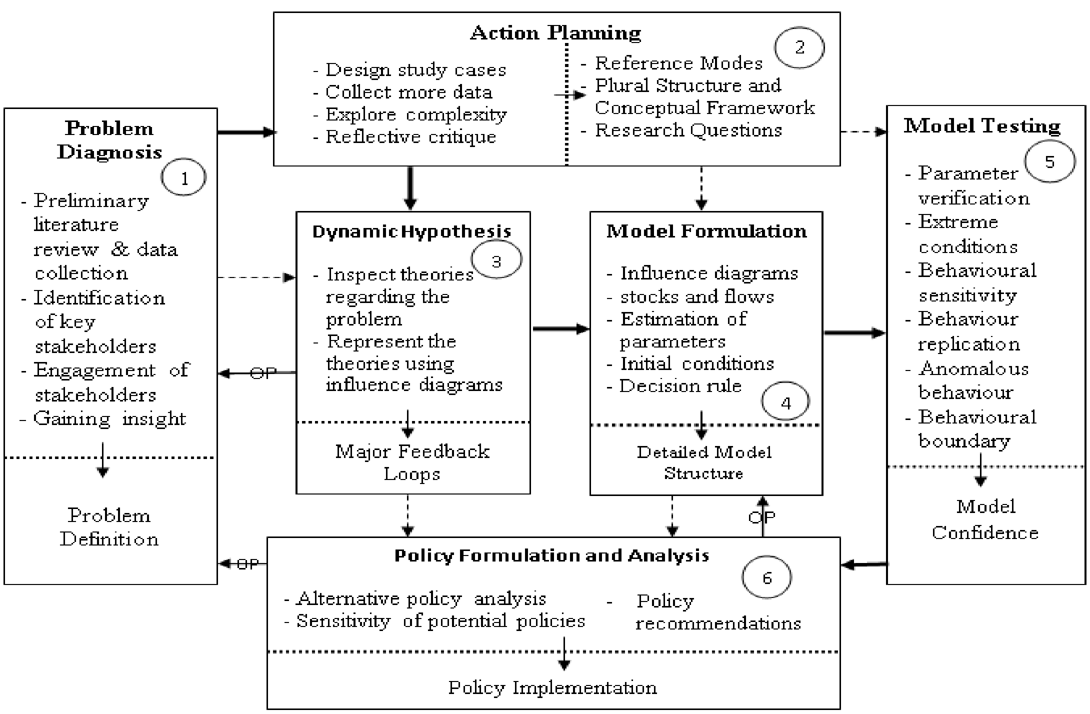

Figure 1. Participative Modelling Process Design

Since evaluation is done at every phase, the broken arrows demonstrate information flow into the destination phase. This information is needed to complete evaluation of the phase's activities against predefined outcomes of the current phase as basis for advanced to the next phase. Arrows within each phase, depict the relationship between the activities and the expected outcome of that phase. Arrows labelled "op" imply optional dependency, i.e., a fall back to a previous phase for improvement of outcomes in the phase(s) concerned. These arrows as shown in Figure 1, are used to complete three cycles: the first is "problem articulation cycle"- involving phases 1-3, the second is the "modelling proficiency cycle"- corresponding with phases 4-6, and last is "solution refinement cycle"- that connects phase 6 to phase 1, resulting into a new modelling cycle. The stepwise details of Figure 1 are discussed next.

Step one: problem diagnosis. In this phase, the researcher must become aware of the real-world problem, one that provides scope for the elucidation of research themes or ideas. Underpinning this initial identification the researcher endeavours to find out more about the nature of the problem and the problem context, who the problem owners are, key stakeholders in the problem solving process, historical, cultural, and political components of relevance, and so on. In collaboration with the stakeholders, the problem is defined, setting the research process to the next phase. Most importantly in this phase, the stakeholder's perception of what constitutes the problem as well as the causes of the problem is asserted.

GOAL: ensure that problem is defined more accurately and thoroughly bearing in mind that a problem well stated is more or less a problem have solved. In addition, phase one explicitly connects to the second phase since the setting of research objectives and framing the intervention in phase two cannot be done independent of problem formulation.

Step two: action planning. In this phase, the research team develops a problem solving strategy after designing study cases, collecting more data, and exploring problem complexity. The outcomes from this stage are reference modes, research questions and detailed documentation of research process (or system description) also known as "plural structure", and the conceptual framework. In developing/refining research objectives, consensus is sought on the basis of all parties (modellers and participants) accepting the legitimacy of the other's contributions. Only then will the action planned or rather specific objectives of the intervention encompass both the modelling exercise and how competency levels of participants in dealing with their practical problems should be addressed.

GOAL: develop a detailed system/model boundary. Specify criteria for evaluating results of modelling exercise including benefits or changes in mental models of participants involved.

Step three: dynamic hypothesis. This phase together with the first two phases constitute the problem articulation cycle: for example, identification of problem stakeholders and problem definition in step one, leads to the design of study cases, eliciting of reference modes, and the model conceptual framework in step two, which underpins the development of dynamic hypothesis in step three. Depending on the nature of the problem, rather than move to step four from step three, a fall back to step one, hence the problem articulation cycle, may be preferred until consensus is reached on the problem to solve. The messier the problem, the higher the iterations of problem articulation cycle. The keyword "articulation" is aptly used to imply that: a complete diagnosed problem relies on stakeholder-provided data on the problem (reference modes) and the research team's ability to represent the problem structurally (dynamic hypothesis).

GOAL: show the section of system's structure or major feedback loops that are responsible for dynamic behaviour of the whole system.

Step four: model formulation. The insights from step three and step two are used in model formulation in this phase. The outcome of this phase therefore, is a detailed model structure. The model structure comprises of influence diagrams that capture relationships between different elements of the system, and stocks and flows diagram for quantitative representation of these relationships. The actual model building is accomplished in this phase and hence stakeholders' contributions are minimal but their involvement is relevant, and must be considered a priori (cf., second step).

In order to reconcile scepticism regarding capacity of rational reasoning and learning in human beings when dealing with complex systems ([19] as cited by [33]) with claims that model building concepts can be easily grasped by stakeholders without prior related skills [27, 37], "modelling proficiency cycle" is be adopted. As such, the smallest model or module that is easier to follow by un-experienced stakeholders is built, tested/verified and simulated in the first iteration, then a larger model is developed in the second iteration, and process repeated until the final model is built. It should be noted that these iterations are necessary if and only if the level of intended learning for stakeholders in phase two included model building, otherwise, stakeholders shouldn't forced to beyond their learning limit.

GOAL: detailed model is built and embraced by the modelling team. It is certainly crucial that communication between the researcher(s) and the stakeholders is maximised so that stakeholders maintain a good momentum to sail through the last stages of modelling.

Step five: model testing. Model testing doesn't require technical knowledge of SD provided the stakeholders are encouraged to learn new but simple validation concepts. Both model structure and model behaviour tests are done in this stage in comparison with reference modes in stage 2. Success in testing of the model creates confidence in the model.
GOAL: analyse simulation results against reference data as basis of gaining confidence in the model built.

Step six: policy formulation and analysis. Phase 6 requires more emphasis by stakeholders especially those at the forefront of policy implementation. Although the researcher monitors policy analysis stage, actual policy changes in real life are effected by the stakeholders. If satisfactory outcomes are realised in this stage then the modelling process is considered successful otherwise, the research team refocus on the problem, amend the action plan and make additional changes to the problem context in a new modelling cycle also referred to as solution refinement cycle.

GOAL: policy implementation including a continuous evaluation of whether the need for further policy extension exists.

Participative modelling in which the researcher/expert control exists as in the case reported here is not without valid criticisms. First and foremost, stakeholders' commitment to action and change beyond the intervention may be weak [22, 33]. Secondly, implementation dynamics prohibits full exploitation of results and recommendations [17]. Both these challenges can be mitigated by the ensuing three cycles during modelling as just discussed and further explored in the following case study discussion.

5. Participative modelling process design in practice: a case study

5.1. Brief Background

The modelling approach presented in this paper was conceived following involvement of the authors in an ongoing quality enhancement modelling project for Makerere University. For over seventy years of existence, Makerere University has been a centre of excellence in sub-Saharan Africa and beyond. However, the implementation of government policy to partially privatise public universities beginning 1992 created new challenges and opportunities for Makerere. On the opportunity side, Makerere was able to supplement inadequate public funding through tuition from private students while maintaining quality. Initial evaluation of this policy change led Court [2] to aptly conclude: that changes long thought to be unattainable and even unmentionable in several African countries, had been achieved by Makerere and a new mindset established that quality and student numbers can coexist. From the challenge side, however, enrolment shot up from 6,352 in 1992 to 34,506 in 2006 [11] amidst incommensurate growth in physical infrastructure, academic staff, basic information and communications technologies, laboratory equipment, chemicals, and other scientific paraphernalia. This prompted negative media reports on declining quality, similar reports from the academic circles [8] and above all the fall in university ranking [11]. The cumulative effect of these reports couldn't but create new pressures on university management to investigate quality improvement policies.

Resolving such complex university quality problems can be difficult; however, the approach Makerere took was to address specific quality problems at autonomous departmental level. For instance, through the recommendation of planning directorate, scaling down of student intake in the humanities-based disciplines by 10% started in academic year 2005/06 and is expected to continue until enrolment matches the supply capacity of the university. The school of graduate studies initiated a project aimed at defining the optimal students' numbers in June 2007. The mandate of ensuring optimal students for each academic unit given available basic resources (teaching staff, lecture and/or laboratory space, and computers) now lies with the quality assurance department, which was transformed into a directorate in January 2008.

Through this new directorate for which the new director is a system dynamics practitioner, a generic tool for quality management decision support was inevitable. Initial conceptualisations of quality problems for Makerere were made and a team of investigators including the director and a doctoral student as main researchers on one hand and members of quality assurance board as stakeholders was instituted to develop a quality management tool for Makarere. For clarity, the director and the doctoral student are the authors of this paper and were already working on SD models for quality in higher education in developing countries. SD modelling approach and specifically GMB was introduced to the stakeholders for adoption in addressing the problem at hand. Incidentally, some of the stakeholders are action researchers and subsequently, the synergy between SD and AR was explored. As a result, the participative modelling process design as already discussed was developed. By explicitly stating the outcomes of every phase in the process design, it became clear what was expected of the stakeholders on the onset and hence greater understanding of the modelling process was enhanced.

5.2. Preliminary Results

By following the steps in Figure 1, six half day long workshops with stakeholders/participants over the period February to June 2008 were held. The first three workshops were consistent with steps 1-3, while the rest followed the modelling proficiency cycle with emphasis on participants learning and proficiency in model building. Details of outcomes from these workshops are discussed next.

5.2.1. Modelling Process. In the first workshop, participants and modellers elicited the perspectives of quality problems at Makerere University, emphasising the most critical ones. Statistical data, e.g., admission trends both at undergraduate and graduate levels, graduation rates, staff employment including part-time staff, staff development, budgeting issues, previous and current research projects, etcetera, from all relevant management units were randomly analysed/reviewed and hidden trends revealed. Both identified data gaps and contradicting data were summarised and deferred to the second workshop.

The second workshop explored issues of problem boundary, synchronised new data with existing data into reference modes, and formulated research questions. The research questions included: a) what influences quality? b) which methods are useful in formulation and analysis of quality improvement policies? and c) how should participative modelling be designed so that the implementation issues rhyme with institutional strategies?. Answers to these questions needed further research and were deferred to the third workshop. Lastly, in this workshop, the possible model sectors were discussed and a complete conceptual framework as presented in Appendix A was sketched.

In the third workshop, answers to the research questions were provided. The reference modes were further analysed and the basic structure responsible for changes in quality over time or simply the dynamic hypothesis was formulated through a series of refinements. Table 1 explores the research questions, while Figure 2 presents the dynamic hypothesis.

Table 1: Exploring the key Quality Management Questions

Question	Corresponding answer in summary
What influences quality?	A number of factors can be identified, but the main ones include: entry criteria, funding, external regulation, policy vaccum/bias, strategic choices, market dynamics, staff qualifications and experience, staff retention, staff comptence, teaching load, class size, student evaluation, ratio of full-time to part-time staff, staff to students ratio, and basic resources (lecture space, computers, library, etc).
Which methods are useful in formulation and analysis of quality improvement policies?	Several methods are available in the literature, these include: data warehousing, data mining, analytic hierarchy process, hierarchical linear modelling, multicriteria decision making, goal programming, bechmarking, statistical process control, participatory action research, and system dynamics. Quality improvement policies, however, are effective when the entire problem scope is addressed. This scope is characterised by: - complexity of influencing factors - non-linearity between variables - presence of multiple feedbacks - soft behavioural relationships - time delays, e.g., staff on training, period of investment in new capacity - dynamics of quality issues reflected by continuously unfolding contingencies With exception of SD, the rest of the methods suggested above only address specific quality problems and not the entire scope. Furthermore, the benefits of SD can be extended when SD is usefully combined with AR (cf., [33]).
How should participative modelling be designed so that implementation rymes with institutional strategies?	The appropriate design depends on pre-intervention planning that should address three issues. First, prioritisation of the development and/or improvement of institutional strategies. Secondly, inclusion of influencial stakeholders in the modelling team. Last but not least, provion of mechanism whereby the exchange of views minimises/avoids the communication dillema such as: - stakeholders regarding their knowledge as superior to systematic engagement - stakeholders answering questions yet unaware that their answers are irrelevant.

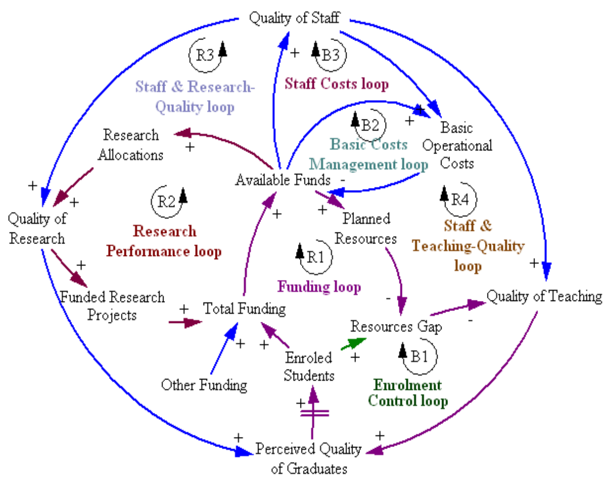

Figure 2: Dynamic Hypothesis for University Quality Management System

The rest of workshops focused on model development. Due to the resulting complexity of the model, viz. the need to maintain stakeholders' participation in modelling, the tasks were broken down into three parts, starting with the smallest model, through an intermediary model, which then evolved into the final one. In this respect, the first model focussed on quality in the context of research, which led to the second in terms of funding, and finally the overall model. In terms of research relevance, the two preliminary models developed so far, have been extended to reflect the Ugandan universities situations, and presented at two international academic conferences.

These preliminary results suggest that the dual aim of AR (practical problem solving and the generation of new knowledge and understanding [40]), can be achieved in participative modelling. In an effort to further justify the relevance of this research, the next section explores effectiveness of the modelling intervention.

5.3. Evaluation of modelling intervention

The evaluation in this section reports on the effects of intervention on individual, group, and the larger organisation (the university) as elaborated in Rouwette et al. (2002). Participation was considered key to success of modelling intervention. As such, participants were required by the end of the second workshop to register either for 'full participation' (participants required to attend/contribute to all workshops and related assignments besides the workshops) or 'selective participation' (participants indicate preferred workshops and why) depending on overlapping work demands. Out of eight participants, five registered for full participation. These participation groupings were indeed significant for the overall evaluations.

5.3.1. Outcomes at Individual Level. Reaction and commitment were the main focus at this level. With regard to reaction, analysis of "reflective critique" reports (feedback elicitation script) for every workshop revealed divergent views on individual outcomes with respect to the category of participation. Two cases are worthy to note: A participant registered for full participation described the appropriateness of the modelling process design:

> I am motivated to participate in all stages of the modelling process by the promises of outputs of every stage; I need to be part of every unfolding output such that I usefully transfer insights of modelling to my office tasks whenever deemed appropriate.

This interesting comment takes the viewpoint of the modelling process design as a comprehensive communication tool for inexperienced modellers.

On the other hand, a participant registered for selective participation described the modelling experience as:

> The process is highly demanding; I am not studying for another degree. Let those who are already experienced do their thing and we do ours, i.e., provide the information we have and share our knowledge.

Generally the reactions make specific links between insight and participation. Specifically, the 'full participation' category more or less reported that participative modelling is useful in formulation and analysis of quality improvement policies, while the 'selective participation' category found participative modelling too labour intensive for its purposes.

Regarding commitment, since in our study most participants are influential on quality policies in Makerere University, their participation in the modelling workshops was a major concern in addition to promoting the recommendations at various policy levels. In this respect, the 'full participation' category indeed participated fully in all the workshops, while the 'selective participation' category were inconsistent even in workshops or stages in modelling in which they had shown interest.

5.3.2 Outcomes at group level. The most pronounced outcome at this level was consensus. The fruits of consensus have already been given, worthy to reiterate, however, are two unique cases: first, the modelling process design that emerged during the pre-intervention meeting (refer to section 5.1). Secondly, the development of the dynamic hypothesis and quality management framework, as early as by the third workshop. Overall, greater exchange of viewpoints led to an extended focus in which a broader view of quality issues including: teaching load, staff development, resources availability, design of new courses, evaluation of students' work and their projects supervision, funding sources, and management of basic operational costs to consider the major ones, were explored in addition to the initial concern (over enrolment, student retention especially at graduate level, and impact of graduates).

5.3.3 Outcomes at organisational level. The study reported in this paper from the onset, was seeking solutions to the quality problems presented in section 5.1. Consequently, some policies relating to quality at university management level have been complemented and others challenged. For instance, previous policies on: scaling down student admission, setting minimum publications requirements for PhD graduation have been complemented, while removal of undergraduate research projects in some academic units have been challenged.

Other new strategies, also complemented by our study, are in the pipeline of implementation, e.g., raising graduate enrolment ratio from the current 10% to 40% (through aggressive prospecting of research funding, enforcing as mandatory a PhD qualification for recruitment of new academic staff), diversification of study programmes and funding sources, and prioritisation of income from students' tuition fees to four major areas, including: teaching, staff emolument, students' research supervision, and expansion. The outcomes at organisational level cannot be exhausted since the effects of participative modelling project transcends the project lifetime, i.e., at least for the case in this paper, three quarters of participants specifically claimed to have adopted feedback thinking in decisions processes at their respective departments. The latter statement, however, is not meant to override some stakeholders' perceptions that good policies on quality improvement in higher education are often not based on systematic engagement with simulation experiments, but on personal knowledge and experience.

6. Concluding discussion

This paper has presented a process model design for participative modelling based on integration of elements of AR concepts into SD. These approaches combined in principle are highly complementary. Consequently the arguments prevalent in system dynamics participative modelling that such a modelling approach supports learning, alignment of mental models, group decision-making and the creation of commitment have been replicated as depicted by the preliminary results discussed. Furthermore, concurrently, both the goals of AR (dual focus on the implementation of planned change as well as knowledge development) and SD (policy formulation, analysis and ultimately implementation) are achievable when the current process design is used.

Lessons learned from using the current modelling process design are three fold: first, involve the stakeholders in the modelling process only to the extent they can contain as opposed to the extent they are expected to participate. After all it may be practically impossible for stakeholders without prior modelling skills to understand not to mention follow the whole modelling process yet their active involvement in particular phases e.g., first two and last two phases is most crucial. Most importantly, stakeholders freely express different perspectives of the problem and possible solutions in the problem articulation cycle. Thereafter, control of modelling process shifts to modellers. Secondly, the modelling project should be divided into modules with defined outcomes so that transition from one module (a smaller model) to the next module (larger model) caters for the difference in learning abilities and/or interest of participants when modelling complex systems. Third, in essence, the more the modules (evolving models), the longer the modelling process, and the greater are the insights from modelling and ultimately ownership of the model.

Several areas for further research can be identified. First, a process design when SD is integrated into AR or participative action research could probably create new ways of problem articulation and subsequent solution processes. Secondly, establishing how the proposed process design can be applied as stakeholder learning-support systems (cf., [31]) may highlight better understanding of interventions in organisations. Finally, can system dynamics models that will trigger organisational change (cf., [17]) be developed using the current process design?

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Appendix A: High level quality management framework for higher education