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Serious games as a social learning tool in formalizing the artisanal and small-scale mining sector in African territories

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Abstract

The literature states that the predominantly “top-down only” approach classically taken to formalise the complex sector of artisanal and small-scale mining (ASM) in Africa has resulted in the design of ineffective and/or incompatible regulations. This paper discusses a complementary “bottom-up as well” approach, based on the joint design, with local stakeholders—some of whom have very low literacy and education—of serious games as an educational tool combined with new management of resources and territories. These games would serve as a social learning laboratory that would (a) provide a secure framework for testing new decisions and (b) help change opinions through deliberations. This paper is theoretical and should be regarded as presenting the design and implementation of active research regarding ASM formalisation in African territories. We argue our proposal by reviewing the literature and field debates and also by applying a solid scientific foundation.

Keywords

Artisanal and small-scale mining, serious games, participatory simulation, African territories

I Introduction and Background

I.1 Artisanal and small-scale mining in Africa: a complex sector

Artisanal and small-scale mining (ASM) in Africa is well-known as an activity characterised by very low productivity (exploitation of marginal deposits), conducted mostly by very poor people (Pelon and Martel-Jantin, 2006; Mandere, 2019). Nonetheless, the activity has substantial potential to provide direct and indirect jobs (Jaques et al., 2006; Hilson, 2016; Mandere, 2019; World Bank ASM, 2019), so the sector is of growing importance for the livelihoods of an increasing number of Africa’s rural population (Jonsson and Brycesson, 2009) and contributes to poverty reduction (Kamwanje, 2019).

The ASM sector is also a complex livelihood system. In this paper “complexity” has two definitions (Fromm, 2004). The first considers complexity as a process: the “*complexity of a system is the number of difficulties an observer is faced with while trying to understand it*”. This inevitably involves multiple stakeholders perceiving the same system differently. The second definition is as a property: “*a system is complex if it can be represented efficiently by different models at different scales*,” This means that a model at a higher scale (space or time) is not sufficiently representative to describe that model at a lower scale, necessitating the presence of both in the same system. In our case, ASM is characterised by complex labour hierarchies (Hilson, 2009) and the social organisation of the activity at a local level (Bolay, 2016). For example, men work primarily in the mines, and women and children work both in and around the mines and at home and must balance mining and household responsibilities (Kamwanje, 2019). Often, ASM activity is combined with farming activities (Hilson, 2009; Hilson, 2016; Etter-Phoya, 2019) to generate income from several sources to manage economic conditions.

Despite the contributions and attractiveness of ASM, at least two correlated concerns exist. First, beyond the observation that most people active in ASM adopt poverty-driven behaviour (Hilson, 2009), certain ASM workers have low to almost no education and low literacy rates (BSR, 2017), resulting in social, economic, and environmental inequalities (Max-Neef et al., 1991). Lack of education in a family is evident when children assist their families in mining (Etter-Phoya, 2019) instead of attending school (INN, 2018). Secondly, a large proportion of ASM workers are in the informal sector, that is, outside any legal and regulatory framework (Pelon and Martel-Jantin, 2006; Mandere, 2019). In particular, not many firmly entrenched “shadow” and illicit buying networks are likely to disappear (Hilson, 2009). The consequences of the unregulated nature of the sector, exacerbated by poverty and insufficient education, are at least twofold. First, informal miners have substantial difficulty accessing essential services such as appropriate technologies, mining skills, and marketing services (Mandere, 2019). For example, when women have poor literacy rates, they often have little to no control over their

income and are frequently cheated by dealers (BSR, 2017) and likely to be excluded from current policy planning to formally regulate the sector (Buss et al., 2019). Secondly, the activity has adverse environmental impacts (Jaques et al., 2006; Pelon and Martel-Jantin, 2006; Barasa et al., 2016; Kamwanje, 2019). This damage to the environment negatively impacts workers' health, for example, the suitability of poor quality water for drinking (Kamwanje, 2019) or workers who are injured because their employer has not provided protective clothing for digging processes (Etter-Phoya, 2019).

The sector's activity would nonetheless continue because it contributes to reducing poverty. The ASM sector should remain, as it cannot afford to be ignored, abandoned, or suppressed (Mandere, 2019). Although it may be informal or illegal, it is not necessarily considered illegitimate by miners or nearby communities who accept it as an alternative source of income (Etter-Phoya, 2019). Consequently, when revising mining policy, this complexity and historical situation must be considered. However, the predominantly "top-down only" approach classically applied to formalise ASM has not sufficiently considered these, resulting in ineffective and/or incompatible regulations (Hilson, 2009).

Therefore, a change of paradigm, using a pedagogical approach, is necessary to progress from the predominantly "top-down only" to a "bottom-up as well" approach. Given the often low literacy and knowledge levels of some ASM local territory stakeholders (e.g. pit owners, workers along the value chain, villagers, local authorities), a change such as inclusion of a strong bottom-up analysis, to formalisation in the ASM sector, requires a more participatory approach (van Asselt Marjolein and Rijkens-Klomp, 2002; Storup, 2013) using at least three stages. The first stage is to listen carefully to the current perception of these stakeholders regarding how their territory functions (e.g., stakeholders' practices, interactions, histories, issues). The second stage is to ensure through social learning (SL) mechanisms that those involved have a shared understanding of that function (without judging whether it is good or bad). The third stage involves both the operational and institutional stakeholders in jointly constructing possible reorganisation scenarios for the territory's future activity, at both the individual and collective levels. Shared understanding is strategically important. For the large-scale-mining sector recognised and audible spokespeople exist (the industry itself); for the ASM sector worldwide, situations are far more uneven: operators are diverse and sometimes incapable of speaking with one voice (Pelon and Martel-Jantin, 2006).

To implement a change of paradigm, local territory stakeholders need education-based tools to first increase their understanding of the complexity of the process and then determine solutions. As stated by Marshall and Veiga (2017), formalisation cannot exist without education, and governments should not demand formalisation of individuals who have no understanding of the benefits of a "legal mining title."

1.2 The role of science

To accompany the process, scientists have a role to play: a role that flows perfectly with the suggestion of Hilson (2009) that the ASM problems mentioned in section I.1 will simultaneously stimulate work and new ideas for research. This will create an ASM policy dialogue that, in the case of Sub-Saharan Africa, is significantly disconnected from the realities on the ground. This proposal would consist of jointly building the future with the stakeholders and using scientific methods to overcome the distribution challenges in the sector. Such challenges cover both economic (i.e., how to distribute wealth among individuals) and ecologic levels (i.e., distribution between those who will reap the benefits of nature's wealth and those who will be harmed by damaging it).

First, these scientific methods should publicly recognise the plurality of values in a non-regulated sector and, in the same way, publicly indicate the issue of the research (or lack of research) for the peaceful coexistence of ASM stakeholders with diverse opinions. They would allow stakeholders (a) to mould more opinions of different scenarios that they would build together and (b) to collectively explain the choice of these scenarios. Consequently, this multi-stakeholder discussion would not be about eliminating contradictions but about admitting them and discovering original means to articulate them and allow action (Chamaret et al., 2007).

Secondly, these scientific methods should propose a laboratory structure where the local stakeholders, regardless of the level of education and literacy, would feel comfortable attempting to move toward

formalisation (moving from their comfort zones, testing new ideas or practices and evaluating their impact a safe (no consequences in the real world) yet serious environment (that could make opinions change).

Thirdly, these scientific methods also must adapt to the technical initiation of targeted stakeholders. Indeed, as reported by Weldegiorgis (2019), ASM is unsuitable for intellectuals; thus, the discussions and language used must be simplified to allow the miners and all individuals at lower literacy levels to become openly involved.

Finally, these scientific methods should also be able to assess how complex the ASM situation is and how complex are the stakeholders seeking a solution. This is difficult as the theory of simplicity that Schumacher (2007) describes: the creation of a tool (and method) whose complexity is not removed but whose visual output is simple and elegant.

1.3 Goal

Using a solid scientific foundation and feedback from discussions about similar cases in the field of resource and territory management, we aim to present and discuss our proposal to implement the concept of serious games (SGs) (Djaouti et al., 2011) as being the simple education laboratory that can accompany the change of paradigm in the formalisation of the ASM sector. In terms of game format, we will not adopt the classical form of a video game (*ibidem*). We will use a game that takes the form of participatory simulation. This is an approach that combines modelling and participation, in the form of role-playing games, to generate experience in an environmental problem (Becu et al., 2017). The role-playing game board will have a computer simulation tool on which a player can rely to make decisions in the game. This simulator will generate a stylised version of the main economic and environmental processes related to the ASM sector's problems, which are not parts of the decisions of game players (e.g., the propagation of contaminants in the subsoil and water, the impact on downstream uses, and the associated short- and long-term economic costs). The advantage of this computer simulation tool is that players can immediately observe the medium- to long-term impact (in the game) of their decisions.

This paper is theoretical because we have neither completed the research nor validated the results from a particular ASM territory. Nonetheless, we argue our proposal by reviewing the literature and field discussions regarding (a) expertise and/or training in ASM issues and techniques in Africa and (b) the scientific implementation of participatory simulation in the African mining sector and natural resource sectors in general (because mining is a multisector activity). We also provide a theoretical (and very simplified) example of how such a game could be conceptualised, by investigating the case of ongoing ASM formalisation policy in Malawi by the establishment of cooperative societies. The choice of Malawi for this theoretical example at this stage of investigation is entirely random. Knowing that ASM challenges are important in many African countries, we could also have chosen any country in the west African area in which the formalisation issue also exists (Tychsen and Charles, 2019).

Societal questions on the formalisation of the ASM sector that these games would attempt to answer are twofold: (a) research on a shared vision of current problems (i.e., SL) and (b) joint construction of prospective solutions. These questions refer to local stakeholders in the territory (e.g., pit owners, workers along the value chain, villagers, local authorities).

When seeking to find a shared vision of current problems, the questions asked (QP) are as follows:

QP1 (the current problem of perceptions): How does each local stakeholder, whether working formally or informally, perceive and understand (a) the challenges related to ASM formalisation, (b) the involved stakeholder's games occurring along the value chain, and (c) the impacts of these challenges on their territory, from their point of view and in their words?

QP2 (initial solutions to the current problem): After the game, and based on the new knowledge acquired (by the game, among others), what would the stakeholders say the (new) reasons were that would prevent or induce them to adhere to the formal sector?

Regarding the step of jointly constructing prospective solutions, the questions asked (QS) are then as follows:

QS1 (proposed solutions): What are the prospective scenarios that each stakeholder would propose for reorganising practices individually and collectively immediately to move toward formalisation (e.g., buying safety equipment despite low revenue but under certain conditions)?

QS2 (evaluation of solutions): For each prospective scenario played (collectively in the game), what would be the impact (still in the game) of the various stakeholders' decisions on the following:

- revenue and profit of each worker along the value chain in the sector?
- workers' health?
- global quality and quantity of environmental pollution emitted for various elements (e.g., water, soil, air, forests, vegetation)?
- effects on how children are educated?

QS3 (solutions selected): In the end, after the game, what would be the scenarios for reorganising practices (new perspectives) that these stakeholders would adopt individually and collectively to work toward formalisation? What are the conditions and/or constraints associated with each scenario chosen and rejected? For each scenario, what would be required for each stakeholder to decide to move the cursor of their indicators and interests (e.g., family revenue) to participate in reaching this collective interest in formalisation?

These questions, generic at this stage, can then be adjusted and refined according to the context of the target application.

The remainder of the paper is organised as follows: Section 2 explains the limits of the state of the art. Section 3 describes our proposal and provides an example (truncated) of how such a game could be conceptualised. An example of the application is the formalisation of the ASM sector in Malawi. Section 4 discusses our proposal; and Section 5 provides our concluding remarks. These remarks include vigilance points that must be monitored when the process is implemented.

2 A review and limits of the state of the art

We established the parameters of our proposal for the SGs we describe by reviewing the state of the art and its limits. These can be classified into two categories: thematic and scientific.

2.1 Thematic parameters: improving the learning of ASM keys and issues by

local stakeholders

2.1.1 Classical learning approach

In the current state, the methods used by an ASM population regarding formalisation are predominantly in two categories: education and technical assistance. The goal of technical assistance varies. It includes identification and development of the best mineral deposits (Martel-Jantin, 2015), maximisation of gold recovery (Marshall and Veiga, 2017), use of appropriate mineral processing centres (Spiegel, 2015), and identification of environmentally responsible practices (Marshall and Veiga, 2017; Kaphwiyo, 2019). The goal of education is also varied: access to markets through cooperatives (Mandere, 2019; Keita, 2019), awareness of key legislation and environmental issues (Spiegel, 2015; PanAfGeo ASM, 2019), awareness of bureaucratic procedures (Marshall and Veiga, 2017), understanding of socioeconomics of ASM in a country (PanAfGeo ASM, 2019), and recommendation and sensitisation to education actions in workplace safety, child labour, and health impacts of ASM activity (Jaques et al., 2006). As a result of these actions, the understanding of ASM organisational and financial structures has improved (Kinyondo and Huggins, 2020).

These actions are generally undertaken by experts and/or researchers in geology or mining, and the educational pathway is often a top-down approach: training authorities and/or experts first, and operators last. This expertise-based approach, also called the classical learning approach, has merit. However, it does not consider each person and his/her individual, complex aspects. For example, as reported by Geenen (2012), little attention has been paid to the broader cultural aspects, which are crucial when

targeting the ASM sector. Although experts may be intellectually aware that such parameters could exist, the individual importance of each ASM member could not always be captured by experts. Consequently, they cannot always provide the appropriate solution to situations partially created by these parameters. An example of such a cultural aspect occurs in Madagascar: customary practices sometimes oblige people to sacrifice zebu (cattle) because the belief is that doing so facilitates mineral discovery (Weldegiorgis, 2019). Another example is the sacrifice scheduler in Mali, which ensures gold panners' protection against bad spirits or the devil (Keita, 2019). According to Rossignol (2018), the technocratic approach which controls modern economies only includes quantifiable data. This economic control in modern society is guided by reasoning dominated by Cartesianism¹. Therefore, the non-quantifiable dimensions of the human phenomena are overlooked, even though they control the economy in the first instance. Lack of consideration of these additional non-controlled aspects is probably one reason Marshall and Veiga (2017) state that educators (the experts) were unable to state what they thought best for miners.

2.1.2 Introduction of Social Learning (SL)

One concept that could help overcome, at least partially, the limitation of the classical learning approach (i.e., omitting personal/complex parameters) in ASM formalisation is an SL approach; more precisely, the implementation of corresponding scientific methodology. According to Freire (Gadotti, 1994), SL breaks with the classical hierarchy model, which has been widely supported in the current, dominant research in which knowledge is transferred from one person to another, similar to a student-teacher model (see the previous section). In SL, by contrast, the stakeholders are also conducting research, by building a vision of research for their own social or professional category (each introducing their independent knowledge) but are then faced with other peoples' experiences. In addition, SL is, according to Rossignol (2018), a safeguard approach against technocratic drift. Indeed, it forms the non-quantifiable, with priority given to the process instead of the result. It requires collective intelligence and satisfactory solutions rather than optimal solutions, and relativisation of the role of the expert. The expert cannot impose solutions for the collective as this is the manner in which the collective group reflects and decides.

In ASM formalisation, the possible effects of not having an SL methodology—beyond the aforementioned effects on the assistance/education program—are (a) the lack of regular dialogue between stakeholders (no prior shared understanding of a situation), which could lead to consequences such as distrust, misunderstanding, and conflict, and (b) the negative economic impacts of this on the stakeholder's territory.

An example of a misunderstanding is the case of children working at mining sites instead of going to school. In some places, this practice is perceived negatively due to the risk of human rights abuses (Vogel et al., 2018) such as human trafficking (Etter-Phoya, 2019) and should be avoided, and in other places, this type of child labour is perceived positively in the local tradition as a social means of learning and integrating children into ASM (Keita, 2019).

Another example of misunderstanding and conflict, at a more political level, is a situation in Zimbabwe (Spiegel, 2015), in which, during the recentralisation of the formalisation process by national authorities, ASM groups and district authorities were ostracised. Thus, what is presented as a formalisation of gold mining and the empowerment of the poor by the national authorities was perceived by local participants as a process of control and coercion. Consequently, trust was weakened between artisanal miners and national authorities and formalisation had been perceived as a threat. A similar case occurred in the Democratic Republic of Congo (DRC) (Geenen, 2012), in which national authorities, supposedly on behalf of formalisation, banned all ASM activities. The government had not undertaken a preliminary discussion with the population and the local socioeconomic consequence of the decision was catastrophic as most local parameters were ignored.

A lack of dialogue and trust in the ASM sector is also observed in land-use conflicts, either between ASM and agricultural/farmer stakeholders (Keita, 2019) or between the ASM population and large-scale mining companies (Bolay, 2016; Keita, 2019). Regarding the latter, Marshall and Veiga (2017), for example, mention the case where large concessions bought by many mining companies are invaded by "informal" and "illegal" miners. This phenomenon causes major conflicts in rural areas, leading in some cases to government-led military interventions. These conflicts are sometimes exacerbated by the

¹ Cartesianism is a form of rationalism.

favouritism shown by the government toward large-scale mining companies, instead of residents, in the issuance of licences by national authorities, such as in the DRC (Geenen, 2012), Zambia (Siwale and Siwale, 2017) and Ghana (Hilson et al., 2018).

A lack of dialogue and trust in ASM is also related to the exclusion of women from the formalisation process (Buss et al., 2019). Women have always played an important role in the social organisation of mining sites (Keita, 2019), and their participation rates, in some cases, are more than 60%, such as in Mali, Guinea, or Senegal (ibidem). Admittedly, for some women, this exclusion may be because of their lack of access to education and awareness of their legal and human rights (BSR, 2017; Tychsen and Charles, 2019), and a weak self-belief that they can become engineers or leaders (Weldegiorgis, 2019). Occasionally, exclusion occurs because men deliberately act to prevent women's access to economic opportunities (Etter-Phoya, 2019). Dialogue cannot then take place.

Finally, a lack of dialogue is also observed between large-scale mining companies and local communities in general, (not only in ASM communities) regarding the implementation of corporate social responsibility (CSR) at African mines, the evolution of which over many decades in the Sub-Saharan area has been reported by Hilson et al. (2019). Indeed, as stated by that work, there seems to be a sizable difference between the needs of affected communities on the one hand, and what mining companies believe to be appropriate CSR and local development on the other hand. Of note is the example of the resettlement of and compensation to local communities by Rio Tinto in Tôlanaro (Madagascar) for ilmenite exploitation (Douguet et al., 2017). In its 2013 report, this company, as reported by Hilson et al. (2019), stated that its general goal was to improve the livelihood of the resettled individuals and future generations. However, in the same year, six members of the Association Fagnomba (meaning "mutual aid") were incarcerated in Tôlanaro because they were the spokespersons of "little persons" (sic) in the region (IP Reunion ilménite, 2013). Not only have these "little persons" been expelled from their lands but the Rio Tinto activity has also degraded the environment. Admittedly, the inhabitants are aware of the positive impacts of this activity in terms of jobs and social action; however, they also feel that the activity is plundering Malagasy lands. The company has a different opinion. This is an example in which the company does not have sufficient knowledge of the dynamics, needs, and aspirations of the local populations it was affecting (Hilson et al., 2019). An improved shared understanding of the resettlement process was necessary.

This list is not exhaustive.

Furthermore, a conflict may not always involve the ASM workers directly but rather at an administrative level and may ultimately affect them. For example, Hilson et al. (2018) describe the conflict in Sierra Leone between two agencies involving ASM worker licence delivery: officials at the National Minerals Agency, responsible "for administration and regulation of the minerals sector," and executives at the Environmental Protection Agency are struggling to work together on most mining-related matters.

2.1.3 The current state of SL relating to ASM in Africa

The literature on ASM formalisation predominantly contains works that we describe as determinants of SL framework implementation. By "determinants," we mean that no concrete SL actions, methodologies, nor tools have been explicitly implemented by these works. Nonetheless, their contributions have created conditions and recommendations for and/or acknowledgment of SL framework implementation.

For example, Keita (2019) suggests that all political or technical interventions should be preceded by advanced sociocultural studies of the network along the value chain. Another example is Spiegel (2015). In his analysis of conflicts between national and local stakeholders during the national formalisation process in Zimbabwe, he suggests, as a topic for further research, the implementation of a more nuanced approach that recognises an integrated understanding of the multiple scales of power relations at play. Weldegiorgis (2019) also recognises the need for multistakeholder dialogue at the local level that should involve women, traditional rulers, media, and religious leaders. Additionally, when Geenen (2012) assessed the other actors in the chain, such as traders and the workers who process the gold, she implicitly considered an SL action—integrating women because most of the women participate in the processing stages (Jaques et al., 2006; Keita, 2019). Finally, in an earlier period, De Soto (2002) argues that the formalisation process should start with the existing "informal" rules that then need to be integrated into a single system from which a new formal legal system can be drawn.

De Soto's work is an SL determinant in the sense that it refers to collective intelligence, a major driver of SL, in ASM. The meaning of collective intelligence is natural and simple when considered in the context of the behaviour of social insects such as ants (Bonabeau et al., 1999). When building their nests, ants have no central engineer who imposes a predefined architecture. Instead, the final nest architecture *endogenously emerges* from the individual interactions of ants: a solution that an individual ant could not have found at its own level and perception. The most notable aspect of collective intelligence is that this emerging solution is "perfectly" adapted to a nest society. We propose that De Soto's reasoning can be followed in the same manner: drawing legal rules from formerly "informal" but acceptable (to some extent) rules that are the result of the collective intelligence of members and as such, are "perfectly" adapted to the territory in question. In summary, *emergence* is key. For example, in places in West Africa (Keita, 2019), the activity espouses local organisational forms of villager, community, and familial structures. These structures are driven by a set of local rules, instructions, and customary dictates that are known and accepted by all stakeholders before arriving at the mining area (*ibidem*). These *emerging* rules may often differ by territory and unlike the above case of Keita (2019), they are not always accepted by all stakeholders in a territory. This non-acceptance is due among other things to inequalities, power dynamics, conflicts, and disputes: situations that are normal within ASM activities and governance practices. Essential to our suggestion here is that (a) these emerging rules should be in harmony with the legislation at a national level (Keita, 2019), (b) the complexity and particularity of the territory and its members and (c) the rules are collectively understood by the stakeholders, even if not accepted by all. These horizontal and vertical considerations, if implemented, should enhance the dialogue between stakeholders in different roles and at different levels. It is important to mention that national authorities are often already represented at a local level to monitor the development of formalisation.

For example, the Burkinabe Precious Metals Office (CBMP) in Burkina Faso (Jaques et al., 2006) is perceived as delivering licences or capturing revenue for the government (tax collection for national development) rather than addressing local livelihood demands (Geenen, 2012). The aforementioned horizontal and vertical considerations would reduce the probability of conflicts.

In summary, the above work illustrates that recommendations or first reflections in implementing an SL framework already exist in the literature. However, no concrete SL methodologies and/or tools have yet been designed.

2.1.4 Introduction of the proposed Serious Games (SG)

In light of the above limitations, we suggest one way of implementing SL when instituting formalisation in ASM: an SG, in the form of a role-playing game. In addition to many arguments already provided in the introduction of this paper, we also propose an SG because of the non-exhaustive features that make it more attractive to stakeholders: images and enjoyment. We also add features common to participative approaches: complexity and if applicable, consideration of the whole value chain, such as was methodologically performed by Le Port (2017) in his simulation of the French aggregates-resources sector along its value chain.

The image feature of an SG is suggested in order to have discussions with people in ASM with low literacy. Indeed, unlike text, which depends on and is used in a given targeted language, images are used by human beings from birth (whether or not they attend school) and are simpler for the brain to process (Learevents, n.d.).

The second feature of an SG is the enjoyment feature. This is crucial in ASM because the sector is the object of conflicts and misunderstandings. This feature should decrease tensions during a dialogue, allowing it to be conducted peacefully for as long as possible. However, the goal of an SG is not to solve an exact real-life concern. The goal is to collect the opinions of each player regarding fictional but meaningful situations and to interpret these opinions. After a game session, an attempt is made to transition from the game to the complex real world and to engage in a deliberation process (paradigm 3 in Figure 3) for each participant, a mental attitude resulting, among other things, from the game.

Finally, the third feature of a game is the complexity feature. This feature means considering behaviour such as the resistance to moving toward formalisation, for cultural, emotional, or historical reasons or from personal experience. This behaviour could result in new situations and solutions unidentified through classical learning.

2.2 Scientific reasons: Advanced scientific work on the participative approach related to the mining sector in Africa

2.2.1 Regarding participatory simulation tools

The literature contains scientific research on the joint construction of SG tools for Africa (in the form of participatory simulation) for environmental management and natural resource applications. There are numerous examples: water resource management, Etienne et al. (2011) in South Africa, Daré et al. (2018) in Ghana and Ducrot et al. (2018) in Mozambique; drought management, d'Aquino and Bah (2014) around the Volta River in West Africa; agriculture management, Roudier et al. (2014) in Senegal; and land use conflict management in Zimbabwe (Perrotton et al., 2017). The assessment is that despite the promising advances of these researchers regarding participatory simulation, one of their similarities is that none of them has considered mining in the studied territory, whether ASM or large-scale.

The aforementioned non-negligible number of SGs jointly constructed with African rural stakeholders involved in the natural resources sector, other than mining – (see Figure 1) shows that they are not reluctant to adopt the participatory simulation approach as one way to discuss their concerns. Therefore, it is not unreasonable to think that ASM stakeholders would also be interested in using such a gaming approach to discuss their concerns, especially as some farmers (i.e., a category of stakeholders that has participated in this SG joint construction) are also miners (Hilson, 2016). Because farmers are not typically viewed as illegal, unlike some ASM stakeholders, we may see a difference in terms of acceptance of the game between those two. This potential difference should be captured by the research team which conducts the process.

Figure 1: A serious role-playing game (in the form of participatory simulation) created for (a) the management of occupation conflicts in Zimbabwe and (b) drought management around the Volta River in West Africa: African rural stakeholders are not reluctant to use a gaming approach to discuss their concerns



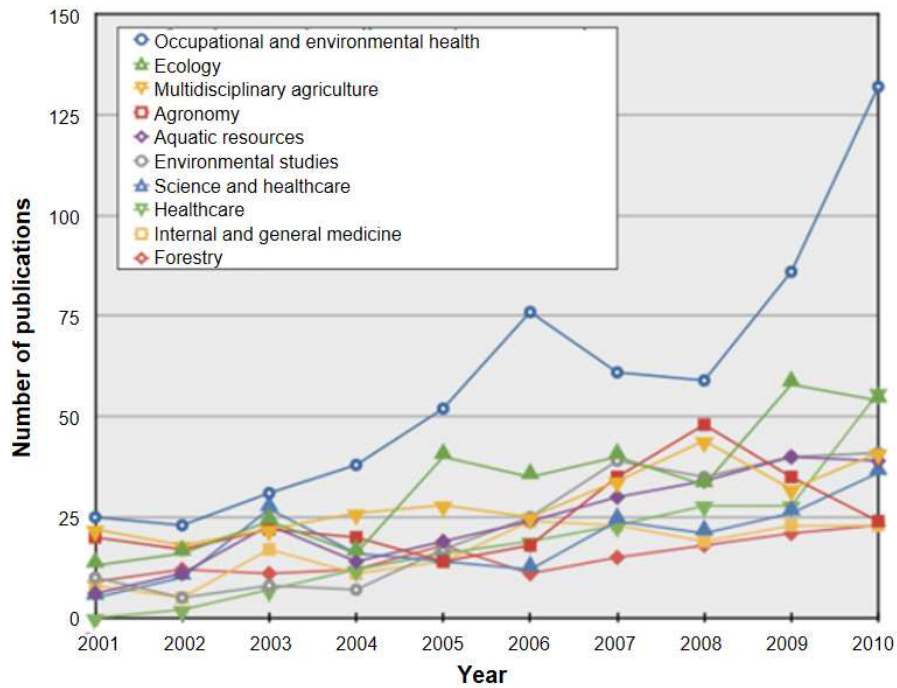
Source: Figure a) is taken from (Perrotton et al., 2017), Figure b) is taken from (Daré et al., 2018)

2.2.2 The participatory action research literature

Globally, as shown by Storup (2013) in a scientometric study regarding subjects or disciplines containing the keyword “participatory”, the mining field is absent (Figure 2). “Discipline” is used here, in the sense of the nomenclature in the “Web of Science” database²; the database has worldwide coverage. This assessment demonstrates the relative novelty of our approach in the field.

² Web of Science (previously known as Web of Knowledge) is a website which provides subscription-based access to multiple databases that provide comprehensive citation data for many different academic disciplines

Figure 2: Number of publications containing the keyword “Participatory,” according to the subject. The figure shows that the field “mine” is absent



Source: (Storup, 2013)

The results in Figure 2 are tempered, however as some literature is oriented to participatory research and applied to the mining sector. We think, for example, of the work of Chamaret et al. (2007) which proposed a top-down/bottom-up approach for the evaluation in multicriteria and multistakeholder terms for uranium mining projects in Arlit (Niger), or that of Douguet et al. (2017) which attempted to answer questions about environmental justice after ilmenite extraction in Madagascar. Outside Africa, but related to extractive industries, research has also been conducted to evaluate multistakeholder, multicriteria supply scenarios for aggregate resources (Douguet et al., 2019). However, these projects did not include participatory simulation in the process and were mainly concerned with large-scale mining rather than ASM. Conversely, the literature has investigated socioeconomic simulations of the ASM sector in Africa (the first idea approaching SGs) but it was developed to produce knowledge only and not of participatory research. For example, simulations have been conducted for the quartz sector in Madagascar (Andriamasinoro and Angel, 2007) and the gold sector in Burkina Faso (Andriamasinoro et al., 2005; Andriamasinoro and Angel, 2012). This simulation research was based on the multistakeholder ABM approach (paradigm 2 in Figure 3). Finally, outside Africa, but related to the domain of the extractive industries, there have been multistakeholder role-playing games regarding aggregate resources (Le Port, 2017), based entirely on a game board without computer simulation. Conversely, with the same type of resources and outside Africa, Schleifer et al. (2019) developed an SG based entirely on computer simulation but without any participatory approach.

In summary, for the ASM sector, almost no participatory simulation approach work has been conducted in an integrated process. The state of the art is either deliberation without simulation, or simulation without deliberation, or role-playing games without deliberation, and so forth. Further, some of this work was not conducted in Africa.

3 Conceptual description of the proposal and an example

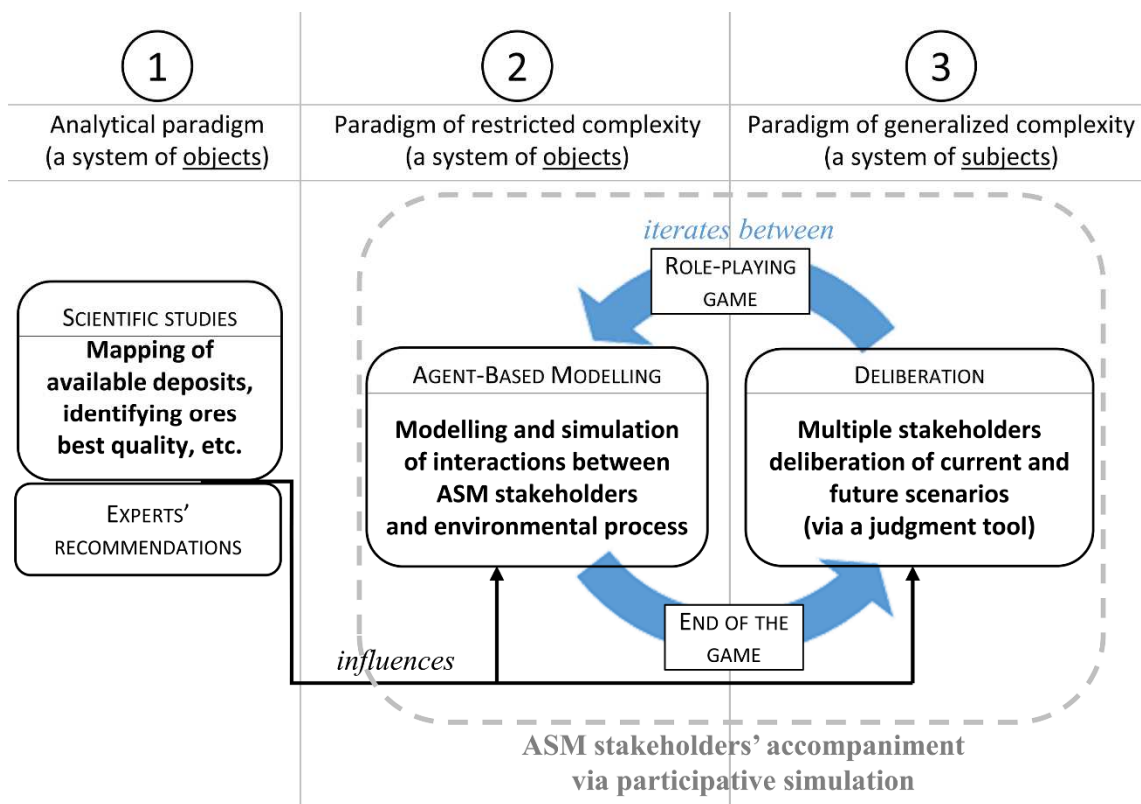
3.1 Choosing a level of complexity

To better account for complexity (or more precisely simplicity) in the ASM system represented, the change of paradigm to be recommended to local ASM stakeholders (see Section I.I) translates scientifically as a change in the conceptual paradigm. To explain this better, we refer to the three complexity paradigms, as defined by Rossignol (2018):

1. analytical paradigm,
2. restricted complexity paradigm, and
3. generalised complexity paradigm.

These three levels are illustrated in Figure 3 and then adapted to our context of ASM (in bold).

Figure 3: The three paradigm levels of a system's complexity applied to the context surrounding ASM stakeholders (in bold)



Source: The initial scheme (in normal font) is drawn from (Rossignol, 2018).

The analytical paradigm (paradigm 1) is the top-down or classic paradigm and is generally adopted by default to solve a problem because it is the simplest paradigm to understand. This scale also called the global scale, is that in which scientific studies (e.g., production of deposit maps) are carried out and decisions (e.g., a country's ASM sector policy) are made when specificities and exceptions are ignored. This level relies heavily on expert opinions and only considers details in a territory cursorily. Consequently, although action on this level is common, demonstrating the complexity at this level is difficult.

The restricted complexity paradigm (paradigm 2) is the start of the bottom-up paradigm and accounts for heterogeneity in a system. In terms of the scientific modeling approach, agent-based models (ABMs) (Le

Page et al., 2013; Railsback and Grimm, 2019) exist. Specifically, these are models composed of a set of relatively autonomous entities that perceive their environment only partially. Each entity may have its own goal.

The generalised complexity paradigm (paradigm 3) is that in which the stakeholders, using what they have learned in paradigms 1 and 2, construct a space for political and environmental debate from a *deliberative* perspective (Frame and O'Connor, 2011): an exchange of points of view through a constructed dialog. The dialogue is based on the qualitative judgment and comparisons of various scenarios (here, reorganisation of practices). In this paradigm, everything is subjective and the scientific method no longer applies.

The direction proposed in this paper focuses on paradigms 2 and 3 through a rotation between SGs (semi-objective/semi-subjective) and multistakeholder and multicriteria deliberation (purely subjective). “Objective” means estimating variables and “subjective” means applying a societal meaning. In terms of the two types of questions asked at the introduction of this paper (Section 1.3), the games serve as responses to QP1 and QS2, whereas the deliberation answers QP2 and QS3. QS1 is a preamble for jointly constructing scenarios.

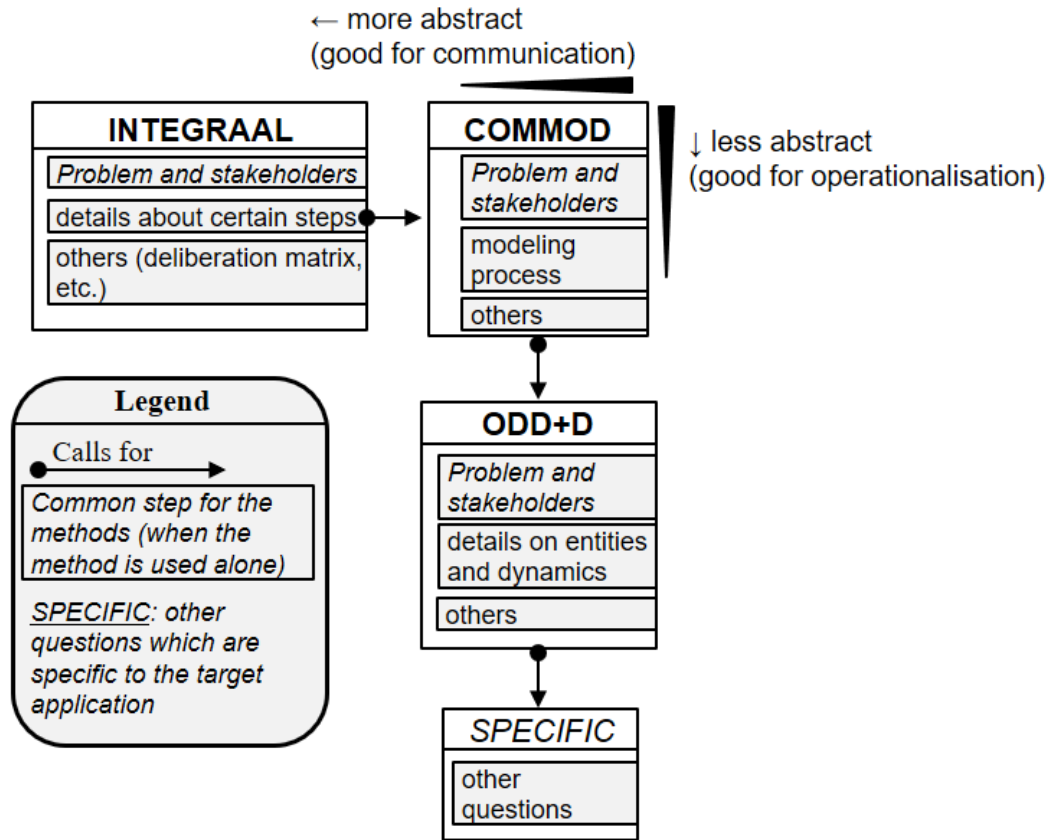
As previously, the game is a participatory simulation tool that first takes the form of a mixed “game board/simulator” that implements economic and environmental processes. It may next take the form of a 100% ABM-based computer-simulation tool. Indeed, as pointed out by Le Page et al. (2010) and Le Port (2017), experiences have shown that a board-based role-playing game should not last too long (preferably not beyond 1 or 2 days) otherwise, participants will tire of it.

3.2 Choice of the methodology

The implementation of our work relies on coupling several scientific and non-scientific approaches (Figure 4). This is unavoidable as it is necessary to integrate two opposite concepts in our complex design. Communication should be as simple and abstract as possible for end-users, without the loss of information. Implementation at the operational level should be as detailed as possible and less abstract for technicians and computers.

We chose to couple approaches that have been previously used in the literature, either for a multistakeholder analysis or for an agent-based design and simulation of a territory. These approaches are INTEGRAAL (O'Connor and Da Cunha, 2011), COMMOD (Barreteau et al., 2014), and ODD + D (Müller et al., 2013). The coupling is characterised by the fact that recursively, a more abstract approach calls for the next less abstract approach during the execution of one or more of its operational functionalities.

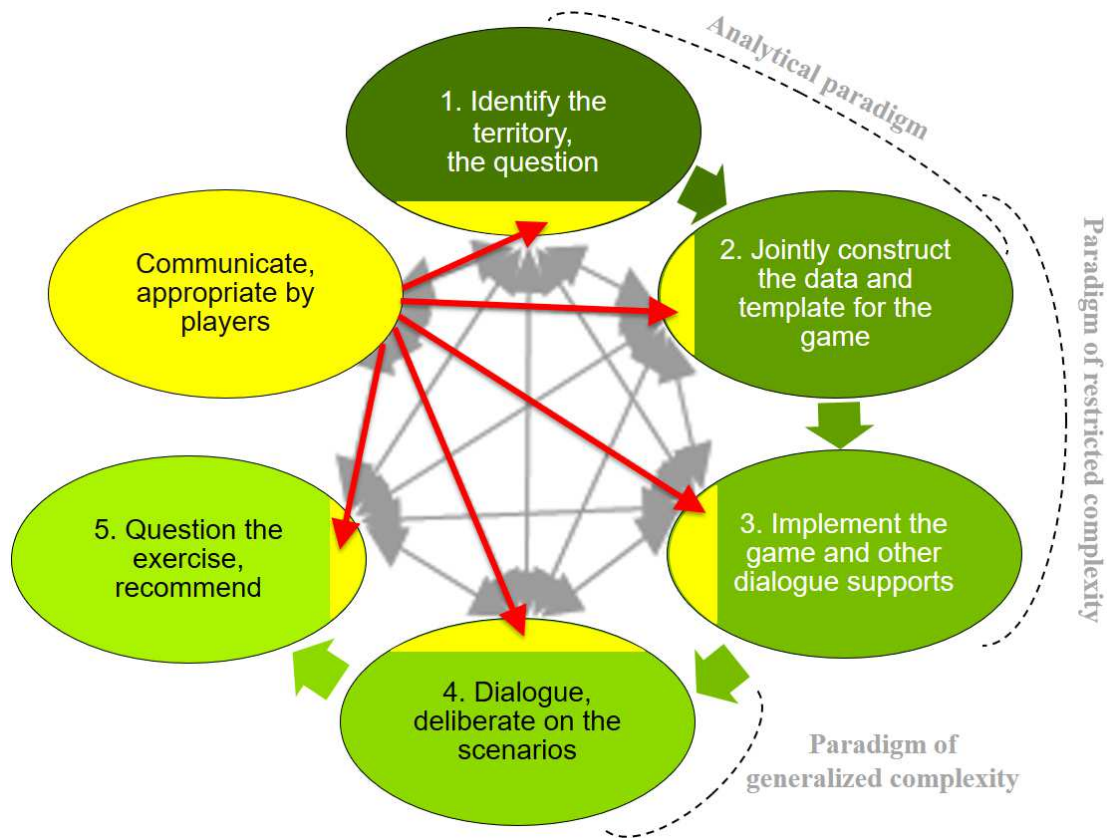
Figure 4: Coupling between the different scientific approaches used for the implementation of our participatory approach



3.2.1 The INTEGRAAL meta-method

The starting point for the coupling is the INTEGRAAL meta-methodology, which aims to engage experts and stakeholders in a deliberative approach. The INTEGRAAL version we use for the formalisation of the ASM sector is an approach composed of five main steps (not necessarily linear) to which are added a communication and appropriation sub-step. This sub-step is conducted at the start and end of each of the other steps and the communication at the end of a step and the start of the next step can be the same. Figure 5 illustrates these steps and how they relate to the three complexity paradigms described in Figure 3.

Figure 5: INTEGRAAL: The meta-methodology envisaged as a starting point for the construction/use of the game and related to the three paradigm complexity levels described in Figure 3.



We summarise Figure 5 as follows:

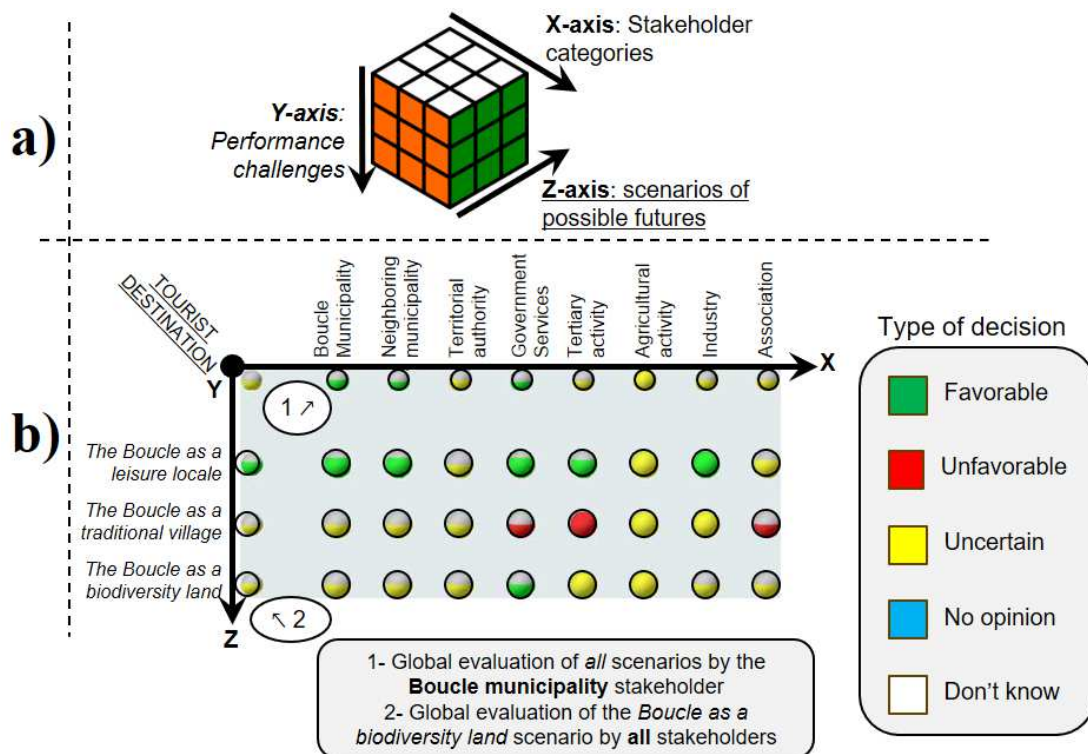
- Steps 1 and 2 (analytical paradigm) correspond to the description of the situation. These introduce knowledge holders and diversity of knowledge (experts' knowledge and/or vernacular knowledge obtained during the role-playing game).
- Step 2 and Step 3 (the paradigm of restricted complexity) correspond to the modeling and implementation of the game. These introduce the diversity of the conceptual approach (COMMODO, ODD+D) and additional knowledge holders from the studied local territory. In all cases, Step 2 also corresponds to the design of challenges and scenarios to be studied.
- Step 4 (the paradigm of generalised complexity) corresponds to the deliberation stage.
- Step 5 evaluates how much the game offers, how it contributes, and how it answers the question asked in Step 1 in a real and complex world. Implicitly, this step determines the recommendations for improving the process in the future.

Regarding Step 4, the work relies on a deliberation matrix (Maxim and O'Connor, 2009; Frame and O'Connor, 2011): a tool for multistakeholder and multicriteria evaluation. Its design is based on the Rubik's Cube (TM). This matrix is a method with an online tool that, as part of joint construction, builds a comparison of the reorganisation scenarios that allow ASM practices to move toward formalisation. It uses three axes (Figure 6.a): (x) "Stakeholder categories," (y) "Performance challenge," and (z) "Scenarios of possible futures." One matrix cell (one intersection of x, y, and z) corresponds to one judgment. The main question to elicit judgment is "according to an actor, what is the ability of a scenario to meet a performance challenge?" A judgment by each actor will be fulfilled based on social value, habits, and knowledge (including but not limited to SGs). A single judgment can be produced through the selection of a basket of 1 to 5 preselected or stakeholder proposed indicators. These are used to characterise relevant attributes of the scenario or choice/action under scrutiny. The system also heavily weighs stakeholder deliberation to articulate the performance challenges and to motivate indicator

selection. This signals a strong vision of social choice and deliberation, and the need, at the operational level, of bottom-up social science. One indicator judgment ranges from “Favourable” (green) to “Don’t know” (white). With this procedure, the judgment at the cell level in the deliberation matrix is obtained as a weighted amalgamation of the qualitative judgments assigned to each indicator in the basket (Frame and O’Connor, 2011). A global score is allotted for a given challenge (resulting from all participants’ evaluations) or for a given participant (for all challenges) based on these weights and colours.

Figure 6.b provides an actual example of judgment on the management issue of the ‘Boucle de Moisson’ municipality in France (Chamaret et al., 2009). The figure particularly illustrates the judgment, by all stakeholders, of the possibility that three scenarios meet the challenge of making Boucle de Moisson a tourist destination. In a judgment in the figure, an indicator weight is represented by the area covered by the indicator colour in the matrix cell.

Figure 6: The deliberation matrix envisaged for judging scenarios. (a) its structure and (b) an example of judgments: here, there is a shared understanding that for most stakeholders, the scenario changing the Boucle to a leisure locale seems to meet the challenges to make it a tourist destination



Source: The example of judgments is taken from (Chamaret et al., 2009)

3.2.2 The COMMOD method

Although INTEGRAAL is an ideal meta-methodology as an entry point and for communicating the work with its rapid and simplified version, it is too abstract for operational implementation of the process. Therefore, we have coupled it to COMMOD to provide additional details. COMMOD expands the process of accompanying stakeholders in 12 steps (distributed here into the various steps in INTEGRAAL). Table I describes this coupling between INTEGRAAL and COMMOD.

Table 1: Details of the coupling processes between the INTEGRAAL method (containing the main steps, the communication sub-steps, and the deliberation matrix) and the COMMOD method (containing the other sub-steps)

Step from the INTEGRAAL process	Details using the COMMOD process
STEP 1: IDENTIFY THE TERRITORY AND THE QUESTION	Step 1.1. - Identify the study territory - Constitute the core team (project team, local stakeholder representatives) - Hold the first meeting with participants to validate the question, the scientific approach, and the calendar
	Step 1.2. - Ensure broader awareness of stakeholders in the territory about the approach (e.g., potential input relative to making decisions) - Adjust/validate Step 1.1 points with these stakeholders - Evaluate the potential for continuing the project or not (will it be successfully implemented or not in the territory)
	Step 1.3. - Provide feedback to stakeholders regarding Step 1 and, if the project continues; communicate the next steps
STEP 2: JOINTLY CONSTRUCT DATA AND THE MODEL FOR THE GAME	Step 2.1. - Create an inventory of knowledge of societal supports for formalisation of the ASM sector in an African territory (state of the art, interviews)
	Step 2.2. - Jointly produce knowledge of desirable current and future operations scenarios in the territory - Structure resulting in societal knowledge in terms of, for example, stakeholders, goals, challenges related to formalisation, and relevant indicators.
	Step 2.3. Construct the model's behavior (a) with the territory's stakeholders and (b) include knowledge from the literature
	Step 2.4. - Completely document the model in a manner that newcomers can immediately understand (e.g., an explanation of the level of simplification and the connection between the game and reality, the reasons for the choice of concepts and data from the literature, uncertainties) - Validate the model: stakeholders determine valid functionalities, remove misunderstood items, validate content, etc.
	Step 2.5. - Provide feedback to stakeholders regarding Step 2 and communicate the next steps
STEP 3: IMPLEMENT THE GAME AND DIALOGUE SUPPORTS	Step 3.1 - Construct the game board and the computer simulation model of environmental processes logistically - Test the whole (e.g., calibration, verification, sensitivity)
	Step 3.2 - The core team formed in Step 1.1 appropriates the game - Preliminary validation: the core team validates functionalities, tests robustness, removes misunderstood items, tests ease of use, etc.
	Step 3.3 - Stakeholders in the territory appropriate the game - Validation with the same criteria used for Step 3.2 but applied to how local stakeholders understand it

Step from the INTEGRAAL process	Details using the COMMOD process
	<p>Step 3.4 Update (in a form accessible to newcomers) the documentation from Step 2 to include the results of sub-steps 3.1 to 3.3</p>
	<p>Step 3.5 Provide feedback to stakeholders regarding Step 3, and communicate the next steps</p>
STEP 4: DIALOGUE, DELIBERATE ON THE SCENARIOS	<p>Step 4.1 - Create one or more thematic sessions for the game: social learning on current operations in the territory and for future scenarios - Use the deliberation matrix: judgment by each stakeholder of the current and future scenarios when faced with the various challenges in the sector (opinions shared and optional updates after collective observation) - Share and validate how different opinions are understood - Seek consensus, without having to produce results</p>
	<p>Step 4.2 - Box the game officially (USB key or CD included for the computer simulation) - Write a report (accessible to newcomers) describing the results of this Step 4</p>
	<p>Step 4.3 Provide feedback to stakeholders regarding Step 4 and communicate the next steps</p>
STEP 5: QUESTION THE EXERCISE, RECOMMEND	<p>Step 5.1 - Hold a summary meeting with the stakeholders on the scientific actions conducted and future perspectives (e.g., additional functionality for the study territory, application to other territories) - Hold a meeting of the core team for the same aspects</p>
	<p>Step 5.2 - Monitor and evaluate the effects of the approach on the participants' practices in the territory - Issue recommendations for the future</p>
	<p>Step 5.3 Update the report issued in Step 4 to include the results of Step 5</p>
	<p>Step 5.4 Provide feedback to stakeholders regarding Step 5 and communicate the perspectives and the recommendations</p>

3.2.3 *The ODD+D method*

To formulate the conceptual model of the game, we will use the ODD + D protocol. Fundamentally, the ODD protocol (Grimm et al., 2010) is used to build ABM models (paradigm 2 in Figure 3). ODD + D is the extension of ODD that establishes a standard for describing human decision-making in ABMs. When in the territory scale, there are strong common points between an ABM model and a role-playing game (e.g., local level, partial perception, heterogeneous decision-making rules), ODD is adapted to conceptualise a game.

The game model formulation is built through the questioning of stakeholders by the modeller, using the guidance questions in the ODD+D protocol, but replacing the term “model” (the initial term used in the questions in this protocol) with the term “game.”

3.3 A conceptualised example (truncated) of the game (Set in Malawi)

3.3.1 Context

Considering the significance of the ASM sector to Malawi’s economy (Section 1.3 briefly explained why we chose Malawi), the Government of Malawi is attempting to implement cooperatives to facilitate formalisation for ASM operators. The government supports cooperatives through technical assistance, grants, loans (through banks), and any other financial assistance to facilitate their activities (Mandere, 2019). However, few functioning ASM cooperatives in Malawi have been observed.

To use SGs to solve this problem, the societal questions set out in the introduction to this paper (see section 1.3) remain valid here, except for an adaptation to QP2 as follows: *regarding the stakeholders operating the informal sector, what reasons would prevent them from or entice them to join the formal sector through a cooperative? Moreover, is a cooperative, for these stakeholders, an adequate solution for formalisation? If yes or no, why?*

All the conceptualisations shown below are imaginary (given that the stakeholders in the field will build the actual game) and truncated (for space reasons—a complete game is generally more complex). They are provided for illustration.

3.3.2 Example of stakeholders and resources

Starting from the societal questions asked and by applying the methodology described in this paper, Table 2 provides various possible elements at the start of the game.

Table 2: Example (imaginary – for illustration) of an ASM SG’s elements

Headings	Description
Sector studied	The artisanal sector in Malawi (Martel-Jantin, 2015): “gold,” “limestone,” “coal,” precious stones, etc.
Stakeholders/roles	Authority, miner/farmer, shaft owner, ore transformer, informal buyer, formal buyer, cooperative, bank, other stakeholders
Resources (and example of relevant properties for the questions)	Shaft (e.g., ore content, size, production cost, pollution generated)
	Vein (e.g., potential)
	River (e.g., with fish)
	Crops (e.g., type, area)
	Forest (number of trees)
Geographic territory (of the game)	Vegetation (e.g. surface)
	Imaginary (does not correspond to the territory’s particular area) but is fairly representative of the elements (stakeholders and resources) being manipulated
Turns	Time step corresponding to 1 turn: 1 month
	Number of turns: to be defined but at least 12 per scenario to be able to play the entire year’s seasons (seasonal rotation between mining and agriculture)

3.3.3 Example of allocation of stakeholder decision-making

Table 3 provides examples of decisions that the different roles would make in the game. The table also suggests the potential number of players per role.

Table 3: Example of decisions made in an SG relative to joining or not joining a cooperative in formalising the ASM sector in Malawi

Role	Goal example	Decision example	Number in the game
Authority	<ul style="list-style-type: none"> - Legalises maximum of miners - Not to be in debt - Protect the environment 	<ul style="list-style-type: none"> - Changes formal substance price and tax or not - Allot license or not - Supports projects (e.g., milling processing centre) or not 	1
Shaft owner	<ul style="list-style-type: none"> - Maximises revenue 	<ul style="list-style-type: none"> - Chooses an identified deposit or not - Hires new employees or not - Determines and distributes employee shares 	1 per shaft
Miner - farmer (mainly men)	<ul style="list-style-type: none"> - Maximises revenue for his family (on the market, is competing with other transformers) - If possible, maximises the family's health 	<ul style="list-style-type: none"> - Goes to the mine or farm - Buys a licence or not (if not already done) - Accepts an education program or not - Gets his children jobs in the mine or sends them to school - Invests in extraction and protection equipment or not - Joins a cooperative or not - If not in a cooperative, finds a market and determines the sales margin in this market 	Between 2 and 5 (1 per shaft)
Ore transformer (mainly women and children): washing activity, essentially	<ul style="list-style-type: none"> - Maximises revenue for her/his family - If possible, maximises the family's health 	<ul style="list-style-type: none"> - Goes to the mine or farm - Gets her/his children jobs in the mine or sends them to school - Determines ore quantity to transform 	2 to 3
Informal buyer	Obtains the maximum market share (in competition with the formal sector)	<ul style="list-style-type: none"> - Develops attraction strategies or not (e.g., loyalty price) 	1
Formal buyer	Obtains the maximum market share (in competition with the formal and informal sector)	<ul style="list-style-type: none"> - Develops attraction strategies or not (e.g., loyalty price) 	At least 2
Cooperative	Facilitates the lives of its members (e.g., financing)	<ul style="list-style-type: none"> - Determines the bank loan level for each member 	1
Banks	Maximises their profit	<ul style="list-style-type: none"> - Determines the loan level for each member of the cooperative (or a common level for the entire cooperative) - Finances the loan application for a member of the cooperative or not 	At least 2

4 Discussions

4.1 Comparison with the participatory action research literature

As discussed in the state of the art regarding the participatory action research literature (see Section 2.2.2), for the ASM sector, almost no participatory simulation approach work has been conducted in an

integrated process. The state of the art is either deliberation without simulation, or simulation without deliberation, or role-playing games without deliberation, and so forth.

In this paper, we attempted to reduce this limit by introducing the concept of an SG supported by the INTEGRAAL method. Although a powerful tool to construct SL, an SG alone would not be sufficient to perform an integrated analysis of the ASM sector in a structured manner that would be understood by stakeholders. This is why we surround the design of our SG by the INTEGRAAL method, which considers the upstream stage (the why and the how of the game construction) and the downstream stage (the interpretation and the addressee of the game results) of its development process inside the three paradigms of complexity (Figure 5). An SG alone cannot play more than one scenario at a time, but the deliberation matrix tool of INTEGRAAL can represent all the scenarios in a single structure (Figure 6.b). This matrix is useful, especially if the goal is to feed the global results of the analysis to stakeholders in a simpler manner. Conversely, this simple matrix tool could not represent the detailed spatial and temporal aspects of a discussion, a capability that an SG has. Besides, not all scenarios proposed by the stakeholders will necessarily be playable via an SG. For example, a consensus could be recognised that the formalisation process for artisanal miners should include a reduction in taxes, bureaucracy, and associated costs (Marshall and Veiga, 2017). These authors then suggested a prospective scenario—“*who produces more pays more taxes*”—whereby the level of bureaucracy increases as tonnage per day, and the amount of taxes increases incrementally within this type of framework. Thus, miner-type definitions become unnecessary. Nonetheless, identifying how to better implement this scenario does not necessarily require the game. This scenario could be directly integrated into the deliberation process (paradigm 3 in Figure 3). The SG is a complementary source of knowledge in addition to that which the stakeholders already have, from legislative documents and previous experiences, for example. At the deliberation stage, all of these knowledge sources (SG or not) could be used.

4.2 Comparison with other multistakeholder knowledge acquisition approaches

Before or in parallel with INTEGRAAL, other approaches to acquiring multistakeholder knowledge already exist and have been applied in ASM formalisation studies. One of these approaches is the individual interview, a classical approach adopted by Spiegel (2015), Hilson et al. (2018), Etter-Phoya (2019), Weldegiorgis (2019), and Kinyondo and Huggins (2020) among others. An interview often allows the interviewer to capture the interviewee’s perceptions about ASM formalisation in his/her own words. However, interviews alone are insufficient to construct an SL structure because normally, different points of view would be encountered in them. In a deliberation context *emerging* points of view, as with collective intelligence must also be considered. However, such an evaluation has not been conducted in the aforementioned literature. We integrate individual interviews into our INTEGRAAL-based SG. However, unlike the aforementioned ASM literature, the interview here is merely one step (cf. Step 2.1 in Table 1) of the whole INTEGRAAL process to build and analyze SL. Another method of acquiring multiple stakeholders’ points of view is an interactive mode of learning through established adult learning principles (O’Neill, 2019), such as that adopted by PanAfGeo ASM (2019) to train ASM participants. This technique is flexible. It highlights the distinct ways adults best respond to learning so that educators consider the ability of each learner. However, it remains a top-down student-teacher scheme that does not consider SL.

Let us also underline that there is one feature which is a major benefit of role-playing games compared with other approaches to knowledge acquisition by multi-stakeholders: role permutation. Indeed, Pink (2013), who based his work on a review of social science studies, emphasised that the capacity of one person (e.g. a member of the authorities in the ASM country) to influence others’ (e.g. a local operator working illegally) lies in the first person’s capacity to negate his/her own experience and put him/herself in the other person’s shoes to imagine those emotions, perceptions, and motivations. From this abstraction, he/she understands the other’s point of view, can put him/herself in the other’s place, and see the world through the other’s eyes. This understanding of the role of other people could reduce tensions and suspicions and should help to implement more appropriate regulations.

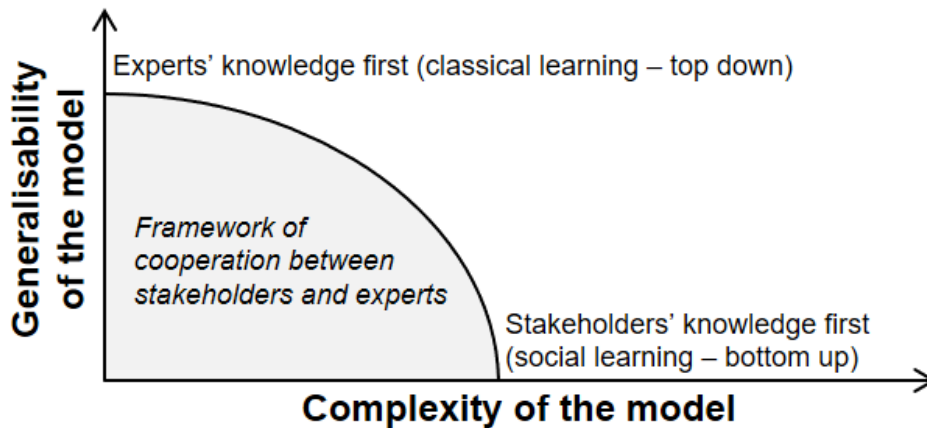
4.3 Towards a combination of SL and classical learning approaches

Throughout this paper, we have highlighted the limitations of classical (top-down) learning used by experts and “promoted” the benefits of serious-game and social (bottom-up) learning used in a participative approach. We think, however, that the best way to generate an outcome that would obtain the maximum support of the involved parties during a deliberation process (paradigm 3) is a combination of both learning approaches. This is true regarding ASM formalisation issues (our context here) but is also true for all territorial multiple-stakeholders issues in general.

The first reason for this, summarizing what d'Aquino et al. (2002) stated regarding land-use conflict management in Senegal using a participative approach, is that this approach should be implemented only as a complement to classical decision-aid tools. These authors assert that when used early with the classical tools, the participative approach would cause an adequate framework of cooperation between stakeholders and experts. The second reason, highlighted by Collectif Commod (2005), is that a deliberative process should be carried out in the form of integrated analysis, that is an analysis which allows the parties to mobilise different complementary tools (databases, maps, planning documents, serious-games, and more) that all serve to help the decision-making process. This also includes tools from experts. The third reason is that it is practically impossible to generalise a participatory approach (Catroux, 2002). Among other reasons, this is due to the uniqueness of the context and the personal implication of stakeholders and the accompanying research team. On the contrary, experts' knowledge used in classical learning comes from experiences obtained from previous cases and/or territories and as such, is more transposable. This expert knowledge is important if the implementation of this serious-game project across African territories is possible. Finally, Rossignol (2018) who designed the three paradigms, stated that all the paradigms are pertinent in their field of validity and that researchers should understand how to navigate from one to another.

To implement this combination of social and classical learning, we think that there are two tendencies: (a) starting from expert knowledge and extending that by adding specific parameters existing in the territory being studied or (b) conversely, starting with social learning first and then bringing experts (b1) to evaluate how the collective group reflects and decides and (b2) to refine the emerging results using their own experiences. These two tendencies are only points of reference knowing that there are no specific boundaries between them, as shown in Figure 7.

Figure 7: Schematisation of the space of the (necessary) collaboration between stakeholders (who often provide social learning) and experts (who often provide classical learning)



Source: The initial scheme (the two axes and the respective labels in bold) is drawn from (Rand and Rust, 2011)

5 Concluding remarks

To help formalise the ASM sector in an African territory, this paper aimed to present and discuss our proposal (theoretical for now) to implement an educational tool based on SGs. These games, associated with deliberation steps, would serve as a participatory tool accompanied by the change in the paradigm in ASM: progressing from the predominantly “top-down only” approach to a “bottom-up as well” approach that considers the sector’s complexity in more detail. These games would be jointly constructed with the local stakeholders and would use solid scientific bases and feedback from field discussions of similar cases in the field of resource and territory management.

These scientific bases and field discussions lead us to think that the approach is promising and would be a notable further research direction to help formalise ASM. However, operational implementation requires close monitoring of key points.

First, before any process could be implemented, the scientific team working on the approach would have to be regarded as legitimate to all stakeholders at all levels, national, regional, and local, of the hierarchy (Perrotton et al., 2017), even if the final target of this approach is only the local individuals (e.g., miners, villagers). Whereas discussions with the authorities seem to be a habitual approach in this quest for legitimacy, building relationships with the population in the villages could be somewhat more difficult and so could take time. There is often a period when upon arrival in the study territory, all computers and notebooks must be closed and researchers simply live daily life with the people, understanding their beliefs, affects, and knowledge. This occasion is also ideal to listen to individuals who might have had bad experiences with previous participatory approaches and attempt to resolve any difficulties as early as possible with adequate clarifications (Barreteau et al., 2010). In acquiring legitimacy the research team also undergoes a stage where the local populace is convinced of its a neutral position. This means that for instance in the event of tense relationships between the local people and their governmental authorities, the research team should not be perceived as being inbiased towards either of the parties. Being neutral also means not making any judgments regarding the illegality of the ASM activity or the education level of the people. To implement this, the game’s supervision and facilitation tasks should be conducted by a person trained to take a neutral position, such as a scientist. Nonetheless, due to the difference in literacy levels in the ASM rural population and the highly hierarchised nature of society in Africa, inequality of information and power between people may be very high. Thus, this neutral posture may well be questioned. Answers to these questions are found on a case-by-case basis, as was discussed by Barnaud and Van Paassen (2013).

Because of this period of uncertain duration spent in the field to acquire this legitimacy, the cost of the

project supporting the process may be affected. Acquiring legitimacy vis-à-vis the local populace is necessary because of the lack of information by the research team is a point of resistance to acceptance of the approach. This could make the process fail.

Secondly, and considering the problem being investigated, the control and research team must be multidisciplinary. It must be composed of geologists and/or miners, economists, environmental specialists, sociologists, IT people, and so forth. If the team conducting the scientific approach is from outside Africa, recruiting people from these disciplines in universities or research centres in the host country would be wise and would strengthen the legitimacy of the research team.

In addition to the aforementioned vigilance points, the scientific methodology described in this paper (paradigms 1 and 2), although developed from solid scientific bases, is only one means of evaluation: its adoption is not obligatory. Researchers who conduct further research on the bottom-up and participative aspects of ASM formalisation are naturally free to proceed otherwise. The same freedom applies to paradigm 3.

The next plan for this work is to implement a prototype version of the game outlined in Section 3.3 to test it with participants in attendance at conferences such as the Colloquium of African Geology (CAG), a series of conferences, the next of which is the twenty-eighth conference ([CAG 28 announcement, 2019](#)). We propose that the CAG is an appropriate venue to share the approach among African stakeholders and that partnerships could be established to conduct such an innovative project.

This plan is a reflection of a global engagement we are currently making as research scientists to conduct a long-term intellectual investigation to find scientific and non-scientific solutions to solving the ASM formalisation issue in Africa. This engagement is valid now and in the future. This paper is the first step towards that long-term objective. These approaches and arguments can be questioned at any time in the research process. Admitting this is an essential attitude to progress ([Collectif Commod, 2005](#)). In addition, our work would preferably be carried out in partnership with organisations and participants around the world, both African and non-African entities. To that end, we will pursue efforts to reinforce existing partnerships while establishing new ones. Partnerships could take the form of a consortium that will continuously respond to diverse tender proposals (on the ASM subject) regularly issued by funding organisations like the World Bank and the European Union. This response is necessary to financially support such investigations for the long term.

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