An Agent-Based Social Simulation for Citizenship Competences and Conflict Resolution Styles

Cecilia Avila-Garzon, Fundación Universitaria Konrad Lorenz, Colombia*
Manuel Balaguera, Fundación Universitaria Konrad Lorenz, Colombia
Valentina Tabares-Morales, Universidad Nacional de Colombia, Sede Manizales, Colombia

ABSTRACT

The development of citizenship competences plays an important role in a complex system like society. Thus, to analyze how such competences impact other contexts is a great challenge because this kind of study involves the work with people and the use of variables that depend on human behaviors. In this sense, many studies have highlighted the advantage of using simulation systems and tools. In particular, the agent-based social simulation field relies upon the Semantic Web to manage knowledge representation in social scenarios. This study focuses on how citizenship competences impact conflict resolution. Moreover, a simulation model in which citizens interact to resolve conflicts by considering citizenship competences and conflict resolution styles is also introduced. It was developed in NetLogo together with an extension that connects it with the ontology of competences. Results show that the higher interactions of citizens-conflicts, the higher level of citizenship competences, and the number of conflicts solved is higher when using citizenship competences.

KEYWORDS

Agent-Based Social Simulation, Citizenship Competences, Conflict Resolution Styles, NetLogo, Ontology

INTRODUCTION

A social system has communication and social structures and represents the environment of individuals to interact (Pieters, 2017). Such individuals are denominated citizens. Being a citizen has been linked with the idea of being a member of a well-structured community or with belonging to a political community (Bratitsis et al., 2016). In such societies, social development is regulated by the interaction between social leaders and the citizens. Under this foundation, some initiatives have been carried out to develop frameworks for promoting the development of citizenship competences, like the framework for the key citizenship competences from Europe (W-reurope, 2015). Moreover, local, and international institutions also foster the development of citizenship competences. For instance, one of the educational targets from UNESCO is citizenship education for sustainable development through the adoption of sustainable lifestyles, human rights, equity, culture and peace, global citizenship, and culture, among others (UNESCO, 2016). In the local context (Colombia), the Educational Ministry defined a citizenship competences model, which focuses on human rights, democracy, diversity, and freedom (MEN, 2011).

The assessment of the acquisition of citizenship competences and how these contribute to the dynamics of the social systems is not straightforward. A standard method to evaluate competences is
to use questionnaires. Ten Dam et al. (2011) conducted a study for measuring citizenship competences in which young people answered a questionnaire based on four social tasks considered as citizenship practices, namely: acting democratically, acting in a democracy responsible manner, dealing with differences, and dealing with conflicts. However, few studies deal with the dynamics of citizenship competences in society. For instance, Mejía et al. (2011) present a multiuser game in which players take individual decisions to advance in the game, focusing on peaceful interaction, participation, and respect. Another example is a videogame focused on citizenship competences in which the gamer acts as the mayor of the city by solving social conflicts (Acosta-Medina et al., 2021). Both studies have the participation of real people interacting in a virtual world. In line with this idea of virtual worlds, the Agent-Based Social Simulation (ABSS) approach is another perspective that allows the creation of virtual worlds. Still, people can be simulated as autonomous entities that interact among them (Caballero et al., 2011).

In this context, this study extends previous research on citizenship competences and conflicts resolution by providing insights into how people might deal with conflicts and how citizenship competences can play an active role when people face different conflicts and make decisions based on their conflict resolution styles. Thus, this study explores, through a simulation scenario, how is the dynamic of a social system when people make decisions to solve a conflict considering citizenship competences and conflict resolution styles. Besides that, both the citizenship competences and the conflict resolution styles were represented using an ontology which is a tool for semantically enriching a context (Sváb-Zamazal, 2020) such as the simulation scenario. On the one hand, citizenship competences are based on the model proposed by Chaux et al. (2004), and the conflict resolution styles are based on the Thomas and Kilmann Instrument (TKI)(Thomas & Kilmann, 2008).

A study about citizenship education states that “quality education and capacity building, notably on citizenship, conflict transformation and human rights are topical in developing peaceful societies” (Parliamentary assembly, 2018). Moreover, Lucey & Giannangelo (2016) point out that simulations have a great potential for teaching about citizenship. In this regard, simulations like the one introduced in this study may help policy leaders or other stakeholders understand the dynamics in a complex system in which people should solve conflicts and identify strategies that favor citizenship education.

This study provides insights into how people might interact solving conflicts when there is the presence of citizenship competences and when not. Results show that the higher interactions of a citizen in different conflicts, the higher level of citizenship competences. Moreover, the number of conflicts solved is higher with citizenship competences. The following sections describe some related work, the materials and methods, the simulation scenario, results, and discussion, and finally, some conclusions and future research directions.

**RELATED WORK**

In an Agent-Based Social Simulation (ABSS) people are represented by agents. Interactions with other agents or contextual elements represent relevant events for people or the social system (X. Li et al., 2008). Moreover, most simulation applications pay special attention to the conceptualization of the domain to be modelled through the simulation. Such a process takes advantage of ontological components to determine the relations between the model and the conceptual domain (Phan et al., 2010) An ontology serves to model different elements from a knowledge domain through classes (Hasan et al., 2021).

The literature on ABSS has highlighted several applications. One of the studies focuses on mobility in European cities (Čertický et al., 2015). The authors introduce a simulation that recreates a complete transportation system involving means of transport, citizens, and mobility schedules in that study—the simulation allowed to observe how changes in the transport system would affect citizens’ behavior. Civil violence is another topic addressed from the perspective of ABSS, in which a social protest can be represented with social factors that influence such a scenario (Lemos, 2018). The cooperative computation can also be modeled as a social system in which rational parties receive incentives to cooperate with each other in the cloud (T. Li et al., 2018). Zausinová et al. (2020) modeled
a corruption scenario and its internal economics and dynamics. Authors from that study concluded that the simulation offers valuable insights for informing an effective anti-corruption policy.

There are other approaches for teaching and analyzing citizenship competences. In the field of teaching and learning citizenship competences, Lucey & Giannangelo (2016) argue that simulations provide unique opportunities for students to be exposed to experiences to reflect about social justice. The authors created two simulations and lesson plans with these simulations for teaching about economics and citizenship.

There are also games for teaching in the field of citizenship competences. For instance, SALTO-YOUTH (2021) offers a board game with a mobile application that offers a simulation and a cooperative game for teaching civic engagement and democracy for youth.

Another example is a framework for modeling human mobility in missing children. Authors suggest that using a mobile app can be combined with the Amber system to make better decisions when a child is reported as missing (Michalitsi-Psarrou et al., 2021). In recent years, the COVID-19 pandemic has attracted the attention of many researchers and some studies related to the simulation of COVID-19 transmission processes have been conducted. The primary purpose of such models is to estimate the spread of Covid-19 over time (Lorig et al., 2021). Behaviors on food consumption have also been modeled through ABSS (Thomopoulos et al., 2021; Trieu & Lin, 2021). Through this simulation authors identified different kinds of arguments for reducing meat consumption such as anthropological, nutritional, health, ethical and, environmental. In the study presented by Plikynas et al. (2022), an agent-based system was developed to model the simple mechanism of how cultural events can impact the empirically observed complex dynamics of social cohesion. Another social topic that has captured the attention of researchers is migration, which is a crucial process that drives demographic changes (Hinsch & Bijak, 2022).

Sansores & Pavón (2004) introduced a framework based on the Ingenias Development Kit (IDK) for the simulation of ABSS on grid computing systems to facilitate the deployment and simulation of complex social systems. In the same vein, Mizuta (2022) highlights the importance of ABSS as a support for decision making in different social situations in some cities. The authors introduced a framework called “X10 -based Agent Simulation on Distributed Infrastructure (XASDI)” for large-scale social simulations and describe some applications of this framework.

This review of literature has shown that here is a variety of applications of ABSS for social systems. However, there is a lack of research on ABSS for analysing conflict resolution and the role of citizenship competences when dealing with conflicts. The importance of citizenship competences is that they are a critical component that drives decision-making processes and therefore influence peoples’ behavior, skills, or knowledge. In that regard, the main contribution of this study lies on the insights into how people deal with conflicts and how citizenship competences play an active role when people face different conflicts. Moreover, this study extends previous research on ABSS by demonstrating the application of ABSS to analyze the influence of citizenship competences on conflict resolution. This study differs from others in the literature because in this study we use an ontology enhanced ABSS to simulate social conflicts resolution considering citizenship competences. The ontology developed and used in the ABSS in this study semantically enriched the simulation scenario with the citizenship competences and the conflict resolution styles. To the best of our knowledge this is the first study that uses an ontology enhanced ABSS for investigating conflict resolution under the influence of citizenship competences. A simulation on this topic would help analyse the dynamics of a social system when citizenship competences are involved.

**MATERIALS AND METHODS**

This section presents the materials and methods for describing the ABSSCC (Agent-Based Social Simulation for Citizenship Competences) introduced in this study.
Materials
The ABSSCC was implemented in NetLogo 6.1.1. It integrates an ontology created in Protégé to represent the domain of citizenship competences and the Thomas and Kilmann Instrument (TKI) styles. Moreover, a NetLogo extension was developed to connect the ontology with the simulation scenario. Details of this software are presented in the description of the simulation scenario section.

The R language and the RStudio environment were used to analyze the results obtained after running the simulation. Results were exported in Comma-Separated Values (CSV) format using the CSV extension included in NetLogo.

Method for Describing the Simulation Scenario
The simulation introduced in this study is described by using the Overview, Design concepts, and Details (ODD) protocol, a method for describing ABSS systems. To have a standard for documenting ABSS, Grimm et al. (2006) proposed the ODD protocol, first published as a standard for the description of ABSS and updated in 2010 (Grimm et al., 2010). Müller et al. (2013) proposed an extension to this protocol as the ODD + D to include elements for describing human decisions. Most recently, the original author of the ODD protocol and other co-authors presented an update for the ODD protocol. They included clarity, replication, and structural realism (Grimm et al., 2020). In that update, the authors provided an ODD guidance and checklist that describes how to apply the protocol.

In the following sections, the ABSSCC is described under the statements of the ODD protocol by including the sections of Overview (Purpose and patterns; Entities, state variables and scales; Process overview and scheduling), Design concepts (Basic principles; Adaptation; Objectives; Learning; Interaction; Stochasticity; Collectives; Observation) and Details (Initialization; Entries; Submodels).

Method for Analyzing Results
To analyze results from the simulation, the Shapiro-Wilk test was applied to verify data normality. The standard parametric t-test was applied to determine if there is a significant difference in the categories of competences for conflicts solved and conflicts not solved. Besides, a box plot was used to graphically depict how conflicts solved and not solved are spread out in the results.

DESCRIPTION OF THE SIMULATION SCENARIO
This section describes the simulation scenario under the ODD (Design concepts and Details) protocol.

ODD – Overview
Purpose and Patterns
The purpose of the ABSSCC (Agent-Based Social Simulation for Citizenship Competences) model is to understand how citizenship competences influence when people solve conflicts. The mechanism driving the explanation is the interaction of people in zones such as work, home, social marketing, and street, which allows people to take part in situations where they should solve conflicts. The model proposes two scenarios for conflict resolution: one with the presence of citizenship competences and the other with the absence of such competences. In both cases solving a conflict depends on the conflict resolution style adopted by the people involved. The ABSSCC model does not focus on realistically replicating any empirically observable system but instead aims to reveal what happens when people resolve conflicts under the presence or absence of citizenship competences.

The general patterns for the ABSSCC model consist of a competence level and a conflict resolution style. Both were selected based on the approaches adopted in our model, the citizenship competences framework proposed by Chaux et al. (2004) and the TKI conflict resolution styles by Thomas & Kilmann (2008). The competence level refers to a person’s level for each citizenship
competences. And according to the TKI, each person has their own style for solving conflicts. The following descriptions may help to understand where the patterns described come from.

On the one hand, the competence level is assigned to each citizenship competences. Such competences come from a model implemented into an ontology based on the Resource Description Framework (RDF). The ontology was developed in the Protégé software. Figure 1 depicts an excerpt of the ontology described. In this excerpt the class Conflict has one instance or individual that represents one of the conflicts (conf_st_2) which is part of the Street zone (esce_Street), and this conflict is associated to a environmental care competence. That competence is under the integrative category according to the competence model adopted.

Figure 2 shows the classes and individuals from the ontology and their relation through the property objects. Although not all classes and instances can be shown in the figure, it shows how conflicts and competences are connected in this ontology.

Figure 1. Excerpt of the ontology for citizenship competences

Figure 2. Classes and individuals in the ontology for citizenship competences
On the other hand, solving a conflict depends on both the competence level of citizens interacting in a conflict and the conflict resolution style of each person based on the TKI model. The TKI styles are:

1. Avoiding: when the person ignores the conflict.
2. Competing: only one person wants to be the winner.
3. Accommodating: one person gives in to the demands of the other.
4. Collaborating: both persons co-create a shared solution.
5. Compromising: both give an acceptable solution.

**Entities, State Variables, and Scales**

The following entities are included in the model: agents representing citizens and grid cells as specific interaction zones. The scenario consists of four zones: work, home, street, and a social marketing area. The last one refers to those places with advertisements or information about things like taking care of a place or throwing litter in the right place, among others. The scenario should have at least two people to interact with in the resolution of conflicts in each zone. In addition, a competence is associated with each conflict, and each time two people interact to resolve a conflict, the level of competences for each citizen is specified as follows.

At the beginning of the simulation, the competence level is defined randomly, and then it is updated each time the citizen interacts in a new conflict. In the simulation, there is a switch that determines if the simulation will run with the presence or the absence of citizenship competences. When that switch is off, conflicts are solved randomly. Otherwise, a conflict is solved considering the level of competence of each of the citizens who interact in that conflict.

The scenario also includes a set of variables that allow storing information about the simulation through time (ticks) and that are also used to keep the information in a comma-separated file using the CSV extension.

One of the scales allows configuring the number of citizens added to the simulation space. This scale ranges from 10 to 500. There is also a parameter that allows defining the number of ticks that the simulation will last.

The simulation space, which in NetLogo is known as the “world”, has 1600 plots divided into a 40 by 40 frame. The origin (0,0) is settled in the left-down square, as shown in Figure 3. This world, in turn, is divided into four zones of equal size; each zone is identified with a different color and represents the zones mentioned above. Within each zone, a maximum of 10 conflicts are defined; each conflict is described in the world by a set of 9 patches. In the simulation world or scenario, each unit of time is represented by a tick.

Figure 4 depicts the initial state of the simulation scenario. In the world there is a label of each one of the four above mentioned zones, together with the options to run the simulation and the output information. There are output boxes that show the conflicts that have been solved and the total conflicts in each zone. In addition,
three charts are presented, one that allows the comparison of solved conflicts versus not-solved conflicts over time, a second graph that represents the behavior of the general competence level of the simulation system, and a final chart that represents the presence of people for each of the zones.

Table 1 shows the values that the parameters and variables involved in this model can take.

**Table 1. Variables of the simulation model**

<table>
<thead>
<tr>
<th>Type</th>
<th>Variable</th>
<th>Default value</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slider</td>
<td>numberOfCitizens</td>
<td>10</td>
<td>10</td>
<td>148</td>
</tr>
<tr>
<td>Switch</td>
<td>withCompetences</td>
<td>Off</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>Entry</td>
<td>ticksNumber</td>
<td>150</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Global</td>
<td>conflictList</td>
<td>0</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>Global</td>
<td>competenceLevel</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Global</td>
<td>zoneName</td>
<td>0</td>
<td>one-of [&quot;Work&quot; &quot;Home&quot; &quot;Street&quot; &quot;SocialMarketing&quot;]</td>
<td>one-of [&quot;Work&quot; &quot;Home&quot; &quot;Street&quot; &quot;SocialMarketing&quot;]</td>
</tr>
<tr>
<td>Global</td>
<td>turtlesToEvaluate</td>
<td>0</td>
<td>one turtle</td>
<td>n turtles</td>
</tr>
<tr>
<td>Global</td>
<td>solved</td>
<td>0</td>
<td>0</td>
<td>n conflicts solved</td>
</tr>
<tr>
<td>Global</td>
<td>notSolved</td>
<td>0</td>
<td>0</td>
<td>n conflicts not solved</td>
</tr>
<tr>
<td>Global</td>
<td>TKI styles (avoiding competing, accommodating, collaborating compromising)</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Global</td>
<td>confSol (Work, Home, Street, SocialM)</td>
<td>0</td>
<td>0</td>
<td>n conflicts solved according to the zone</td>
</tr>
<tr>
<td>Global</td>
<td>totalConf (Work, Home, Street, SocialM)</td>
<td>0</td>
<td>0</td>
<td>total conflicts according to the zone</td>
</tr>
<tr>
<td>Global</td>
<td>peopleAt (Work, Home, Street, SocialM)</td>
<td>0</td>
<td>0</td>
<td>The sum of citizens that passed by the zone</td>
</tr>
<tr>
<td>Global</td>
<td>csvData</td>
<td>0</td>
<td>0</td>
<td>n rows</td>
</tr>
<tr>
<td>turtles-own</td>
<td>individualCompetences</td>
<td>0</td>
<td>0</td>
<td>n competences</td>
</tr>
</tbody>
</table>
Process Overview and Scheduling

The simulation runs under the present or absence of citizenship competences. In both cases, a TKI style is selected per conflict. For the first case, the model analyzes the level of competences of each one of the agents that interact in a conflict, and a TKI style is selected to determine whether the conflict is solved or not. Therefore, a conflict is solved if either of the two agents present in the conflict has a level of competence greater than or equal to 5. Each time a conflict is solved, the level of competence of each agent increases by one unit. In turn, the calculation of the general level of competences is considered to contrast it with the conflicts that have been solved.

In the simulation scenario, the following instructions for citizens are considered:

- All citizens in the scenario move randomly.
- Each citizen is set in one of the zones of the simulation scenario (work, home, social marketing, and street).
- According to the zone, a unit is added to the variable that counts the number of citizens of the respective zone.
- The color of the plot is identified for the citizen currently being evaluated.
- According to the color of the plot, the neighbors who are in the same conflict are identified.
- The resolution of a conflict begins whenever two citizens are interacting with the conflict.
- If the simulation runs without considering the competences, the conflict is randomly solved and the TKI style selected.
- If citizenship competences are being considered, it should be verified if each citizen already has the competence associated with the current conflict or if it is necessary to add it. Each time a new competence is added to the list of individual competences of a citizen, the level of competence is determined through a random number ranging from 1 to 10. A 1-10 rating scale can be used for reporting competence grading (Aithal et al., 2019). If the competence already exists in the individual list of competences, it is not necessary to retrieve its current level value. In our simulation, the level of competence is a number that defines if a person has good attainment of the competence or not, where ten means the good achievement of the competence and one means that the person needs to work more on that competence.
- If the level of competence of any of the two agents is greater than or equal to 5, it is considered that the conflict can be solved or not according to the TKI style selected and, in this case, the conflict would be solved the level of competence of each of the citizens present in the conflict is increased. These rules are described in the Adaptation section.

ODD – Design Concepts

Basic Principles

The simulation model is focused on the Agent-Based Social Simulation (ABSS) field. This field is based on the concept of computer simulation, which is defined as the representation of something (Starbuck, 1983) and has been adopted in a wide range of topics such as climate (Ziervogel et al., 2005), natural disasters (Mustapha et al., 2013), transportation (Hager et al., 2015; Tchappi Haman et al., 2017), and food (Zia et al., 2018), among others. In the human behavior field, computer simulation seeks to represent people’s behavior. However, it does not mean that the simulation must look exactly like the real world (Dutton & Starbuck, 1971). This is because of the complexity of social systems and the vast number of variables involved in cases where the observation is based primarily on human behavior (Müller et al., 2013).

The development of citizenship competences has been fostered by national and international entities with a particular focus on citizenship education. This social component influences the development of political regulations and decision-making processes (UNESCO, 2016). Understanding the dynamics of a social system that involves citizens acting with citizenship competences has not
been addressed from the use of computational techniques, which would contribute to an approximation about the dynamic of the social system in social tasks such as the resolution of the conflicts.

Because social systems are complex systems with real-world entities and their behaviors and relationships, it was identified that the use of ontological engineering allows the modeling of knowledge domains and that combining it with other areas such as agent-based social simulation allows describing the dynamics of a social system (Peristeras et al., 2009). Thus, the simulation model uses an ontology developed to represent the citizenship competences domain and simulates a case study involving the use of the ontology. The use of the ontology is possible thanks to the development of the NetLogo extension (ontoquery) for retrieving certain classes of individuals from the ontology. Our extension was inspired by the work by (Polhill, 2015), who developed a NetLogo extension that allows extracting ontologies from simulations based on NetLogo. The queries to the ontology are executed using SPARQL (Bassiliades, 2020).

Regarding the citizenship competences, we adopted the model proposed by (Chaux et al., 2004), which involves citizenship and peace, citizen participation, and plurality. Besides that, such model defines five categories of citizenship competences, namely: communicative, cognitive, emotional, integrative, and knowledge. The abovementioned ontology is based on these five categories, and specific competences were defined for each category. At the same time, the ontology includes the conflicts to set in the simulation scenario and the competence associated with each of them.

Adaptation

The model has an adaptive behavior for determining whether a conflict is solved or not. As mentioned before, in the simulation scenario, there is a variable to determine whether the citizenship competences are considered or not when running the simulation (withCompetences). Moreover, there are some rules for determining when a conflict is solved or not considering the TKI styles (1. Avoiding, 2. Competing, 3. Accommodating, Collaborating, 5. Compromising). These rules are described as follows:

1. Case one: withCompetences = true
   - R0: If both citizens’ competence level in the conflict is less than five the conflict is not solved.
   - R1: TKI = 1
     - R1.1: If the competence level of both citizens has risen a higher level (8 or more), the conflict is solved otherwise the conflict is not solved.
   - R2: TKI = 2
     - R2.1: One of the citizens is selected randomly.
     - R2.2: If the winner has a competence level greater than the other, the conflict is solved otherwise the conflict is not solved.
   - R3: TKI = 3
     - R3.1: As one of the citizens should give into the demands of the other, the conflict is solved.
   - R4: TKI = 4
     - R4.1: If the competence level of both citizens is equal or greater than 5, the conflict is solved otherwise the conflict is not solved.
   - R5: TKI = 5
     - R5.1: The acceptable solution is defined as having a competence level between 3 and 6 (both included). If both agents meet this requirement, the conflict is solved. Otherwise R5.2.
       - R5.2: If the competence level of both citizens has risen a higher level (8 or more), the conflict is solved otherwise the conflict is not solved.

Case two: withCompetences = false
• R1: TKI = 1
  ◦ The conflict is not solved.

• R2: TKI = 2
  ◦ R2.1: The conflict is solved with a random value between 1 and 2; if the number is two the conflict is solved otherwise the conflict is not solved.

• R3: TKI = 3
  ◦ Two random values from 1 to 10 are selected. Then a number between 1 and 2 is chosen randomly and this corresponds to one of the previously chosen values.
  ◦ R3.1: If the value of the winner is greater than the value of the other, then the conflict is solved otherwise the conflict is not solved.

• R4: TKI = 4
  ◦ Two random values from 1 to 2 are selected.
  ◦ R4.1: If both values are the same, the conflict is solved otherwise the conflict is not solved.

• TKI = 5:
  ◦ A random value from 1 to 10 is selected.
  ◦ R5.1: If the value is between 3 and 6 (both included), the conflict is solved otherwise the conflict is not solved.

Objectives
The objective measure used by the simulation to decide whether a conflict is solved or not is by one hand - with the presence of competences- the level of competence that have each of the citizens involved in the conflict and its TKI style, and by the other hand, - with the absence of competences - according to the TKI style.

Learning
In this model, each time a conflict is solved, a citizen scales upon the level of the competence or competences involved in the conflict.

Interaction
One citizen interacts with another citizen because they move randomly and meet each other in a conflict. Interactions are thus a consequence of two citizens meeting in a conflict identified by its patch color (pcolor) in the simulation scenario.

Stochasticity
The individual level of competence, the TKI style to select, and the decision of solving or not a conflict when the citizenship competences are not considered are modelled randomly.

Stochasticity is present both in the movement of citizens and in the resolution of conflicts when there is an absence of citizen competences. This is because it is not easier to predict either the places where a person can live in their daily lives or the exact competence level they have. With a small number of citizens, it is hard to observe what is happening with the competences level and the conflict resolution. Therefore, it is recommended to use a high level of citizens present in the simulation scenario. From a certain point of the time (tick), it would be possible to observe if the mean of the level of competences reaches a maximum point and the dynamics of solved and unsolved conflicts tend to be constant. The number of ticks can be configured in the scenario.

Collectives
The model includes one collective representing the citizens who interact in pairs in a specific conflict resolution. In this case, each conflict consists of a set of 9 patches with a unique color. A conflict resolution is activated if two citizens have the same patch color and if that color is included in the conflicts list.
**Observation**

The graphical output of the simulation scenario shows each zone with a unique color, as well as each conflict is represented by a unique color. Citizens’ locations are also shown. The model makes the citizens move randomly. Summary statistics on the number of conflicts and conflicts solved per zone are provided via plots and counters.

**ODD – Details**

**Initialization**

Some technical details of the simulation scenario are described as follows.

We developed an ontology to represent the citizenship competences and the conflicts to set in the simulation scenario. The ontology was developed using the Protégé software (Standford, 2017). The ontology has 17 and 15 relations with the type SubClassOf. Moreover, 26 individuals were created in the ontology to represent the kind of competence (14), examples of conflicts (8), and the scenarios (4).

There are also three NetLogo extensions we included:

1. ontoquery: we developed this extension in Java and the NetLogo 6.1. API. This extension allows making queries over the ontology by using the JENA’s API, which is a semantic web framework for Java. The extension involves the use of the ontology described before.
2. array: an extension included in NetLogo to manage arrays.
3. CSV: an extension included in NetLogo used to export data from the simulation.

The simulation environment was developed using the Logo programming language under the NetLogo tool. Figure 5 depicts an architecture diagram with all those components that were developed or used for implementing the simulation scenario including the ontology, the NetLogo extensions, the simulation environment, and the files for output data.

**Figure 5. Architecture of the simulation scenario**

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Figure 6 shows the files required to run the simulation (three folders with the extensions array, csv and queryonto and the main executable file with all the source code of the simulation). To run the simulation, it must be installed NetLogo 6.1. The simulation was tested under the Windows operative system.
In NetLogo, there are some technical concepts that are described as follows:

- **Patch**: The NetLogo world works under a grid based on a coordinates system, like the Cartesian coordinate system, where each point with x and y coordinates is represented by a square that receives the name of patch.

- **Agent**: Objects or entities with data, behaviors and separate execution contexts. Graphically, each agent in NetLogo is represented by a sprite. NetLogo has four types of agents namely observer who performs global operations like clear-all or set up ticks; patches who are stationary agents that are represented by a square in the grid of the scenario and each patch can have each own colour and label; turtles who are mobile agents who move independently in the scenario and can have each own shape, colour, size and label; links who connect one turtle to another.

- **Breed**: Each turtle (agent) can have its own breed, and a breed is a type or category that can be assigned to an agent or to a set of agents.

- **Procedure**: Set of steps written to perform a specific action like the behaviours attained to the agents. Each procedure stars with the word “to” and finishes with the word “end”, instructions in the middle of those words are the steps to follow.

Regarding the initialization of the scenario, there is a breed of agents named “citizens”. Citizens are randomly placed on a zone and their individual list of competences is initially empty. It is possible to determine the number of citizens who will be present in the simulation by selecting a number on the scale of citizens’ number. It is also possible to define whether to consider or not the citizenship competences through the switch included for this purpose in the simulation scenario. The scenario also includes an input for defining the number of ticks. Once these variables have been defined, the “Setup” button is used to locate the necessary elements in the simulation scenario.

Once the setup has been initiated, each one of the four zones receive a zone name, and the conflicts are added in each zone (from one to ten). These conflicts are visually identified by little squares in the zone. Each conflict is added to a list of conflicts, and it is defined as a global variable. Such list contains both the zone name and the competences associated to each conflict. At this point the ontology is queried by using the ontoquery extension which receives two parameters, the zone name and the current list of conflicts as depicted in Figure 7.
Then the “Go” button allows to start the simulation and it will stop until the number of ticks defined is reached. Finally, the Restart button can be used to clear the scenario and re-initialize the variables. Figure 8 depicts the initial conditions of the simulation. In the main scenario, each of the four areas (work, home, street and social marketing) contains little squares with a unique color. Those squares (consisting of 9 patches each one) represent the conflicts. Besides that, there are a random number of individuals (agents representing citizens) in each zone. There is also a slider for setting the number of citizens, a switch for indicating if the simulation runs with or without competences, an input of the number of ticks, and the output boxes and charts to show the conflicts solved and not solved per zone, the summary of conflicts solved vs not solved, the competences level and the presence of people per zone.

**Figure 8. Initialization of the simulation scenario**

![Simulation Initialization](image)

**Input Data**

Entries for the simulation scenario are the number of citizens ranging from 10 to 500, the conflicts settled in the scenario (at most ten per zone), the number of ticks, and the selection for running the simulation with or without the citizenship competences.

**Sub Models**

Each sub model is written as a procedure in the scenario. The sub models that integrate this scenario for the ABSSCC are movement of the citizens, defining the name of each zone, obtaining a conflict and its competence, adding the conflict to the list of conflicts, selecting a TKI style, conflict resolution based on the level of competences and the TKI styles, conflict resolution based on a random number and the TKI styles. Table 2 describes each of the procedures of the above-mentioned sub models.

**RESULTS AND DISCUSSION**

Through the iterative execution of the simulation, different behaviors can be observed in the results obtained. On the one hand, when considering citizen competences (case one), it is observed that the number of solved conflicts grows on a scale greater than the number of conflicts that are not solved. On the other hand, when citizenship competences are not considered (case two), it is observed that the number of unresolved conflicts is greater than the number of resolved conflicts. The results of the ABSSCC simulation of these two cases are presented in Figure 9 for with the presence of citizenship competences and in Figure 10 with the absence of the competences. The test presented in that figures consisted of 200 citizens that were set in the scenario and, the simulation ran until 800 ticks for both.
Table 2. Sub models included in the ABSSCC

<table>
<thead>
<tr>
<th>Movement</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>right random 360</td>
<td>A random direction is selected, and 2 units are defined for going forward.</td>
<td></td>
</tr>
<tr>
<td>forward 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Defining each zone name</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>if(patch-quadrant = list 1 1)</td>
<td>Each zone receives a name depending on the quadrant coordinates.</td>
<td></td>
</tr>
<tr>
<td>{ set zoneName “SocialMarketing” }</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if(patch-quadrant = list 1 -1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ set zoneName “Street” }</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if(patch-quadrant = list -1 -1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ set zoneName “Home” }</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if(patch-quadrant = list -1 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ set zoneName “Work” }</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obtaining a conflict</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>array:from-list query:ontology zone conflictsList</td>
<td>A new conflict and its competence are retrieved from the ontology. The “ontology” query receives to arguments namely: the zone name and the list of conflicts in order to verify that a conflict would not be added twice.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adding the conflict to the list</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>set eachConflict lput conflictName</td>
<td>A conflict consists of a conflict name, the name of the zone in which the conflict was set, the corresponding patch color and, the competence associated.</td>
<td></td>
</tr>
<tr>
<td>set eachConflict lput zone eachConflict</td>
<td></td>
<td></td>
</tr>
<tr>
<td>set eachConflict lput color_p eachConflict</td>
<td></td>
<td></td>
</tr>
<tr>
<td>set eachConflict lput competence eachConflict set conflictsList lput eachConflict conflictsList</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selecting a TKI style</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>let tkiSelect one-of [“avoiding” “competing” “accommodating” “collaborating” “compromising”]</td>
<td>A number from 1 to 5 is set for each one of the TKI styles.</td>
<td></td>
</tr>
<tr>
<td>let tkiNumber 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if (tikiSelect = “avoiding”) [set tkiNumber 1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if (tikiSelect = “competing”) [set tkiNumber 2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if (tikiSelect = “accommodating”) [set tkiNumber 3]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if (tikiSelect = “collaborating”) [set tkiNumber 4]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if (tikiSelect = “compromising”) [set tkiNumber 5]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conflict resolution with competences</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>to-report solving-conflict-with-competences [agents]</td>
<td>The list of agents to evaluate consists of the subgroups which contain first agent and its corresponding competence level, the second agent and its corresponding competence level, and the current patch color. Then a TKI style is selected. These pieces of information are used to decide if a conflict is solved or not depending on the rules described previously.</td>
<td></td>
</tr>
<tr>
<td>;; code</td>
<td></td>
<td></td>
</tr>
<tr>
<td>;; this reports true or false</td>
<td></td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conflict resolution without competences</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>to-report solving-conflict-randomly [agents]</td>
<td>The list of agents to evaluate consist of the subgroups which contain the first agent, the second agent, and the patch color. The decision of solving or not a conflict depends on the rules described previously. In his case, the level of competence of the citizens is not considered.</td>
<td></td>
</tr>
<tr>
<td>;; code</td>
<td></td>
<td></td>
</tr>
<tr>
<td>;; this reports true or false</td>
<td></td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
cases (with and without competences). For each case, three kinds of results are presented (conflicts solved vs not solved, competences level and presence of people per zone).

The presence of citizens per zone was approximately equal. For the case one (with competences), there were more citizens in the Social Marketing zone (with 28.20%), meanwhile for the case two (without competences) there were more presence of citizens in the Street zone (with 26.84%).

As for the conflicts solved per zone, Figure 11 shows the solved vs not solved conflicts per zone comparing with and without the presence of competences. The Work and social marketing were the zones with the highest number of conflict interactions (more than 1200) (see Figure 11a). While Home, Street and Social Marketing had a similar behavior in terms of the interactions with conflicts per zone (more than 1300) (see Figure 11b).
Another aspect also considered in the case two, is the category of competences. In the ontology developed (Figure 2), individuals represent each one of the four zones (scenario in the ontology), each competence (grouped by categories classes in the ontology) and, each one of the conflicts (with its associate competence). In the case one of the simulation, competences are considered and the competence level of each citizen influences in the decision-making of solving or not a conflict. Regarding the categories of competences, Figure 12 depicts the distribution of conflicts in such categories with a proportion from 14% to 25% for each category. These categories were defined in the ontology according to the citizenship competences model adopted in this study (Chaux et al., 2004).

![Figure 11. Conflicts solved vs not solved per zone in a) with competences and b) without competences](image1)

![Figure 12. Distribution of conflicts per category of competences](image2)

The distribution of conflicts solved versus conflicts not solved was also analyzed. Data collected from the simulation is normally distributed according to the Shapiro-Wilk test with p > 0.05 (solved = 0.7311, not solved = 0.3046). The standard parametric t-test was used to identify if there was any difference between both the solved and the not solved conflicts. Results from the t-test revealed that there was a significant difference between conflicts solved and not solved with t = 3.3299, df = 52.064, p = 0.001602. Moreover, Figure 13 presents the box plot for each category differentiating between conflicts solved and conflicts not solved. In all categories the number of conflicts solved is higher than the number of conflicts not solved.

Although the avoiding TKI style assumes to ignore the conflict, there is a variant for the case one (with competences). If the conflict competence level for both citizens interacting in a conflict is
higher than 8, the conflict is solved (rule R1.1 from case one). This means the citizens have reached a good competence level that allow them to solve in a better way a conflict. The box plot depicted in Figure 14 describes the level of competence reached for all the dataset of conflicts in which the citizenship competences were considered. This allows to confirm that conflict resolution benefits from integrating citizenship competences.

Figure 13. Distribution of conflicts Solved vs Not solved per category of competences

![Box plot showing distribution of solved vs not solved conflicts per category of competences.](image1)

Figure 14. Not solved vs Solved conflicts with competences

![Box plot showing the competence level for solved and not solved conflicts.](image2)

Regarding the TKI styles, accommodating was the style more adopted by the citizens when solving a conflict considering the citizenship competences. Meanwhile, competing was the preferred style in the simulation without competences. Table 4 shows the percentage of conflicts solved by TKI style.

As for the TKI styles, since individual competences level improves each time, according to Figure 15, the accommodating, and the compromising TKI styles reached the higher levels of competence. However the TKI style selection deepens on a stochastic variable and for that reason, these results do not follow the same pattern in studies based on the TKI model such as the one reported by (Thomas et al., 2008) in which depending on an assertiveness level results indicate that competing and collaborating styles increasing for higher values of assertiveness while avoiding and accommodating decline.
Overall, the results reveal that citizenship competences impact positively on conflicts resolution. Moreover, during the simulation run it was possible to observe how the general level of the competences improved and contributed to have more conflicts solved.

**CONCLUSIONS**

In this paper we introduced the ABSSCC, an agent-based social simulation that involves the use of citizenship competences for conflict resolution interactions. Tools like this may contribute to interpret the dynamic of social interactions of citizens and how the level of citizenship competences influence the decision-making process. Since the simulation model is focused on conflict resolution, we also adopted the TKI conflict resolution model to differentiate the way a conflict can be solved in both cases, when there is presence of citizenship competences and when not.

The use of a simulation scenario was applied considering advantages reported in the literature for the agent-based social simulation field. This study focused on comparing the dynamics of the simulation scenario when using citizenship competences and when not. In a real scenario it would not be possible to compare different outputs or to change variables of the social system. Thus, our model may serve so that researchers or decision-makers can observe the dynamics of the society when people interact with others by making decisions on how to solve a conflict based on competence levels and TKI styles.

In a real-world scenario, this simulation may contribute to analyze the complexity of a social system which involves the use of citizenship competences because policy makers could observe what is the result after running the simulation when configuring certain parameters and also could identify

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**Table 4. Conflicts solved per TKI style**

<table>
<thead>
<tr>
<th>TKI style</th>
<th>With competences</th>
<th>Without competences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Avoiding</td>
<td>5.72</td>
<td>0</td>
</tr>
<tr>
<td>Competing</td>
<td>15.73</td>
<td>30.28</td>
</tr>
<tr>
<td>Accommodating</td>
<td>33.80</td>
<td>28.27</td>
</tr>
<tr>
<td>Collaborating</td>
<td>17.62</td>
<td>15.38</td>
</tr>
<tr>
<td>Compromising</td>
<td>27.13</td>
<td>26.07</td>
</tr>
</tbody>
</table>

---

**Figure 15. Level of competence per TKI style - conflicts solved with competences**

---

Overall, the results reveal that citizenship competences impact positively on conflicts resolution. Moreover, during the simulation run it was possible to observe how the general level of the competences improved and contributed to have more conflicts solved.
other parameters that can be included and programmed in order to observed if a specific strategy to implement can be effective or not so that people gain or improve their competences.

A limitation of this study is that the tests conducted in the simulation model focused on the competences level, the categories of competences, and the TKI styles of conflict resolution. However, the details and specific variables of each individual competence are not considered due to complexity of the citizenship competences model. A future line of research may involve extending the simulation model to consider such level of detail of the competences.

Technical contributions of this study involve the development of the simulation scenario in the NetLogo tool and the development of an extension for NetLogo which allows to connect an RDF ontology with the simulation scenario. Such NetLogo extension was written using the Java programming language and the Jena framework which is used for developing semantic web and linked data applications. Due to the advantages and multiple uses of linked data (Avila-Garzon, 2020), further investigation, and experimentation into the use of linked data for this kind of social studies is strongly recommended.

Finally, the use of emerging technologies may help the ABSS applications to have a little bit of more realistic elements by configuring 3D environments. Indeed, NetLogo has an option to create this kind of scenarios. Besides that, a technology that has been recently used to simulate real spaces o to superpose real information in a virtual environment is augmented reality (Bacca, 2017).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in OSF at https://osf.io/4r9q6/?view_only=160c20f7984d48738ee9cf38854c9e73

DECLARATION OF INTEREST STATEMENT

No conflict of interest declared.

ACKNOWLEDGEMENT

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REFERENCES


NOTATIONS AND ACRONYMS

Notations and acronyms used in this paper are listed alphabetically in Table 5.

Table 5. Notations and acronyms

<table>
<thead>
<tr>
<th>Notation/acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSS</td>
<td>Agent-Based Social Simulation</td>
</tr>
<tr>
<td>ABSSCC</td>
<td>Agent-Based Social Simulation for Citizenship Competences</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma-Separated Values</td>
</tr>
<tr>
<td>IDK</td>
<td>Ingenias Development Kit</td>
</tr>
<tr>
<td>ODD</td>
<td>Overview, Design concepts, Details</td>
</tr>
<tr>
<td>ODD + D</td>
<td>Overview, Design concepts, Details and human Decisions</td>
</tr>
<tr>
<td>TKI</td>
<td>Thomas and Kilmann Instrument</td>
</tr>
<tr>
<td>XASDI</td>
<td>X10 -based Agent Simulation on Distributed Infrastructure</td>
</tr>
</tbody>
</table>

Cecilia Avila received her bachelor’s in computer science from the Universidad Distrital Francisco José de Caldas in 2011 (Bogotá, Colombia). She also holds a Master in informatics from the University of Girona (Spain, 2013) and a PhD in technology from the same university (2018). She has participated in local and European research projects in the educational technology field. She is full-time professor and researcher at the Fundación Universitaria Konrad Lorenz in Bogotá (Colombia) and her current research is about the use of agent-based social simulation, linked open data, immersive technologies, and web accessibility and usability. E-mail: cecilia.avilag@konradlorenz.edu.co and linked open data.

Manuel Balaguera is PhD in Engineering from the Universidad de los Andes (Bogotá, Colombia), MSc in Physics and Physics from the Universidad Nacional de Colombia. He is associate professor at the School of Business at Fundación Universitaria Konrad Lorenz (Colombia). Manuel have participated in research projects in fields such as computational and applied physicist, modelling and simulation of complex systems. His current research interests are: Complex Systems, Scientific computing, Biomedical Engineering, and Applied Physics. E-mail: manueli.balaguera@konradlorenz.edu.co

Valentina Tabares is Computer Systems Manager of the Universidad Nacional de Colombia - Manizales and Master in Systems Engineering of the same university. She received her PhD in Engineering in 2019. Valentina belongs to the research Group in Adaptive Intelligent Environments - GAIA and her research interest educational technology, artificial intelligence, web accessibility. Currently she is full-time professor and researcher at the department of computer science at the Universidad Nacional de Colombia. E-mail: vtabaresm@unal.edu.co