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Interactive learning environments (ILEs) as effective tools for teaching social sciences

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Abstract

Schoolteachers could enhance learning in social science courses by using teaching tools that favour a methodological approach focused on the topics' basic structure rather than on facts. An innovative system dynamics social-based ILE built with a social constructivist approach is presented here. The pedagogical futures of this ILE are then analysed. The effective impact of different instructional approaches inspired by social-based ILEs on student learning outcomes is also discussed. The ILE and the related inquiry-based instructional approach seem to help students understand fundamental concepts more easily, thus making the topic more comprehensible and helping students place the social facts into a structured scheme.

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Keywords: Interactive learning environment, social sciences, constructivism, educational technology

1. Educational technologies that aid teaching

It is now well known that in order to ensure an effective professional service a teacher should not only know how to use new educational technologies (Moersch, 2002; Sandholt, 1997 Lemke, 2003), but also integrate them with the content and overall teaching approach in order to make the most of their potential. In this regard, some authors have suggested the use of a Technological Pedagogical Content Knowledge (TPCK) framework, highlighting the positive effects generated by the integration of these three dimensions for the effective management of learning processes (Koehler & Mishra, 2008; Mishra & Koehler, 2006, Graham et al., 2009).

However, despite the increasing availability of ICT-based teaching tools and the widespread awareness of teachers of the importance of using ICT-based teaching methods (Khine, 2001), relatively few teachers are using

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such methods in their actual teaching. The marginal implementation of ICT-based teaching tools in educational contexts can be attributed to the insufficient technical knowledge and skills of teachers; however, numerous studies have shown that even the beliefs and attitudes that teachers have in regard to these methods have a decisive influence on whether and how they will be used in class (Hermans, Tondeur, van Braak, & Valcke, 2008; Wang, Ertmer, & Newby, 2004 Ertmer, 2005). For example, Higgins & Moseley, (2001) showed that the opinions of teachers about the validity of the constructivist approach to the design and management of educational activities significantly influences whether and how teachers use ICT-based teaching tools in their classes. Other researchers, however, have shown that teachers who adopt a learner-centred teaching approach manage to integrate their technological knowledge, pedagogical and content more effectively (Honey and Moeller, 1990). Still other scholars have indicated that when ICT-based teaching tools are adopted, they are often used in a technocentric way, not taking due account of the complex relationships between the dimensions of technology, pedagogy and content (Harris et al., 2009).

2. Game-based learning technologies

Among the educational technologies applied to classroom settings, game-based learning technologies have aroused increasing interest in the last few years (Spires, 2008).

The benefits of these educational technologies are related to the fact that they can simulate real-world phenomena easily, thus favouring a learning mode that is more closely connected to students' personal lives (Spires, Rowe, Mott, & Lester, 2011). It has also been shown that the use of these educational technologies produces a positive effect on students' learning because they involve students in an intrinsically motivating learning setting (Foster, 2008; Papastergiou, 2009).

Although now quite common, game-based learning technologies are currently applied mainly in the field of STEM education, a curriculum based on the idea of educating students in four specific disciplines – science, technology, engineering and mathematics – with an interdisciplinary and applied approach (Meluso, 2012, Miller et al, 2004; Miller et al, 2006). There are very few game-based learning technologies applied to the social sciences, and this is probably due to fact that the technological models that underlie them are ill-adapted to the typical content of the social sciences, which often is characterized by the highly complex relationships between the variables involved.

Thus the need emerges to identify a new family of game-based learning technologies based on methodological assumptions that allow for their application even in the social sciences.

3. Toward a system dynamics-based interactive learning environment

For years the system dynamics methodology has been used to implement educational programmes in scholastic institutions at all levels. Even though system dynamics was first developed as a management discipline to understand how the policies of corporations produce successes and failures, it was quickly transferred and adopted in education. From this point of view, Forrester (1997) underlined that "there are several dozen K-12 schools now doing excellent work, and several hundred doing something (valid) … In K-12 education, system dynamics modeling has been applied to mathematics, physics, social studies, history, economics, biology, and literature."

System dynamics is a methodology for understanding the behavior of complex systems over time. It deals with internal feedback loops, time delays, stocks, and flows that affect the behavior of the entire system. These elements help describe how even seemingly simple systems display baffling nonlinearity (Sterman, 2001; Repenning, 2001.

Generally speaking, system dynamics can:

- analyse a phenomenon in a systemic perspective, considering the complex and often non-linear relationships between the key variables that define it
- understand how the behaviours displayed by a given system (phenomenon) are generated by a well-defined structure characterized by interconnected feedback loops and generally represented by a causal loop diagram (CLD).

- analyse the effects of one’s personal decisions and those of others on the behaviour of the system through a simulation model that also has the purpose of identifying unintended and counterintuitive consequences.

As far as the application of system dynamics to learning in the scholastic context of social sciences is concerned, the benefits derive from the possibility to:

- go beyond the limits of an educational approach based solely on an analysis of facts, allowing students to be leaders in the process of identifying the structure underlying the phenomenon being considered (Bruner, 1963)
- enhance the memorization of the details that characterize a phenomenon in light of their placement within a structure whose meaning is clear to the student (Bruner, 1963)
- gain a thorough understanding of a phenomenon without settling for a merely basic understanding, especially when the phenomenon is complex (Bruner, 1963)
- encourage the process of generalization of acquired skills by analysing and investigating a phenomenon in order to understand the dynamics underlying other isomorphic phenomena (transfer of learning) (Bruner, 1963) through the identification of systemic archetypes (Senge, 1990).

4. The proposed SD-based ILE for the learning of social science: The dynamics of Nuclear Weapons

The main goal of this paper is to present a System Dynamics-based Interactive Learning Environment (SD-based ILE), built in accordance with the constructivist approach, for learning in the realm of the social sciences.

In order to verify whether the SD-based ILE can legitimately be considered a constructivist teaching method, we will evaluate the applicability of the four main constructivist criteria defined in Baviskar et al. (2009):

- eliciting students’ prior knowledge;
- creating cognitive dissonance;
- application of the knowledge with feedback;
- reflection on learning.

Such criteria are based respectively on the following four assumptions:

- any new knowledge acquired by the learner must be based on a system of prior knowledge;
- cognitive dissonance is generated when the student becomes aware of the substantial differences between his prior knowledge and the newly acquired knowledge;
- the student is engaged in the double task of assimilation of new knowledge and the accommodation of the (prior) existing scheme (knowledge) that no longer works and must be transformed into a more differentiated and complex pattern;
- after having acquired and verified the new knowledge, the student is brought to reflect not only on the new learning, but also on the processes that generated such learning (meta-cognitive activities).

The proposed SD-based ILE and the related inquiry-based instructional approach should help students understand fundamental social science concepts more easily, thus making topics more comprehensible and helping students place the social facts into a structured scheme.

The proposed SD-based ILE will be described adopting the Technological Pedagogical Content Knowledge framework (Mishra & Koehler, 2006)

4.1. The content of the proposed ILE

The historical and documentary research method has enabled us to identify the principal content areas of the proposed SD-based ILE.

The content is linked to historical events, and the most important ones are shown in Table 1.

Table 1. Major historical events that characterize the dynamics of Nuclear Weapons.

1. The Manhattan Project. The first atomic bomb was made by a multinational team of scientists, members of the so-called Manhattan Project, at the laboratories in Los Alamos, New Mexico, in 1945. The first nuclear test in history took place in New Mexico, USA on July 16, 1945 as part of the Manhattan Project. This project was considered essential by the United States in order to win the war against the Third Reich.
2. Immediate effects generated by the success of the Manhattan Project. On August 6 and August 9, 1945 the United States dropped two atomic bombs on the Japanese cities of Hiroshima and Nagasaki, leading to Japan's surrender and ending the Second World War.
3. Short- to medium-term effects produced by the success of the Manhattan Project. After World War II, nuclear weapons were acquired by all major world powers: the USSR in 1949, the UK in 1952, France in 1960 and China in 1964. They were later acquired by other countries, too.
4. Medium-term effects produced by the success of the Manhattan Project. As a result of growing stockpiles of nuclear weapons, a "Cold War" regime was established in which the two opposing blocks (led by the US and the USSR) were aware that they could destroy each other merely by using nuclear weapons (the doctrine of mutual assured destruction or the balance of terror).
6. Long-term effects produced by the success of the Manhattan Project: The Cuban Missile Crisis. The Cuban missile crisis was a bitter confrontation between the US and the USSR that began in April 1961 and was caused by the decision of the USSR to install a battery of nuclear missiles on the island of Cuba. The crisis came to a climax on October 15, 1962 and lasted thirteen days. After several days of tension, Khrushchev, in response to the position taken by Washington, ordered the withdrawal of the missiles in exchange for the promise by the US not to invade the island and to remove its Jupiter missiles installed at military bases in Turkey and Italy.
7. Short- to medium-term effects produced by the Cuban crisis: the signing of the first International Treaty (Partial Test Ban Treaty). This treaty, signed on August 5, 1963, forbade the Signatory States from conducting nuclear tests in the atmosphere, above ground or under sea, leaving the possibility open for underground tests.
8. Short- to medium-term effects produced by the Cuban crisis: the signing of the Non-Proliferation Treaty (NPT) It was signed initially by the United States, the United Kingdom and the Soviet Union in 1968. France and China acceded in 1992.

Figures 1 and 2 illustrate the chronological development of worldwide nuclear testing totals divided by country and the stockpiled warhead count by year, respectively.

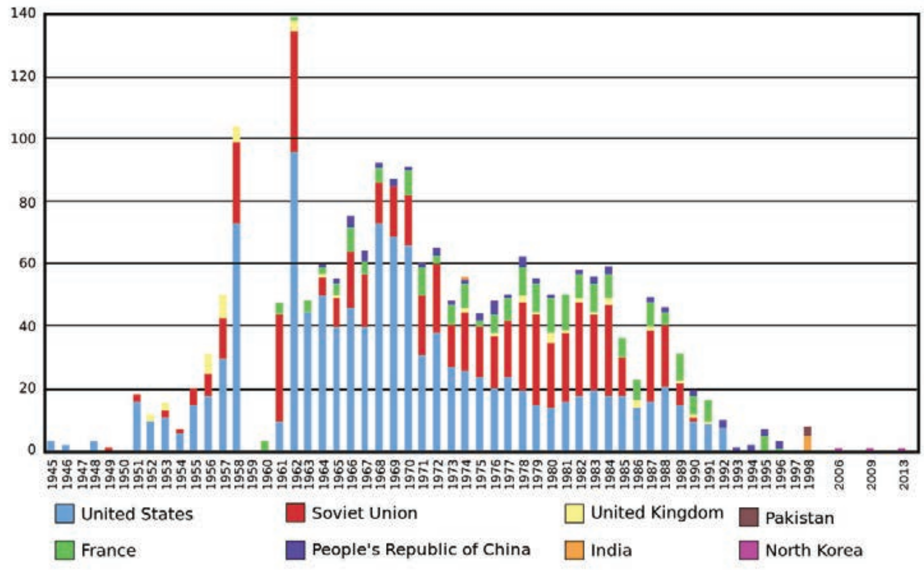

Figure 1. Worldwide nuclear testing totals by country (1945-2013)

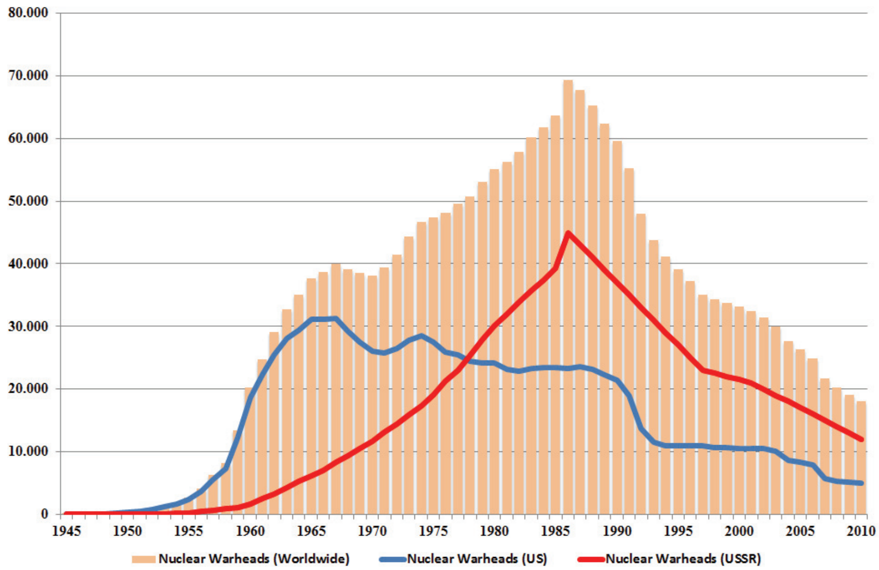

Figure 2. Stockpiled warhead count by year (source: Norris et al., 2010)

4.2. The pedagogical approach of the proposed ILE

In opposition to the traditional lecture-based deductive approach that typically presents historical facts to describe the phenomenon of nuclear escalation from 1945 to the present day, the pedagogical approach on which this SD-based ILE is based meets the criteria for a constructivist teaching method.

4.2.1 Eliciting students' prior knowledge.

Since the teacher's task is to facilitate the incorporation of new knowledge into the complex system of constructs possessed by the learner (Vermette et al., 2001; Windschitl, 2002), he/she must no longer consider him/herself as a simple lecturer, adopting the traditional lecture-based deductive approach, but must become advisor and coach to students so that they can go beyond the teacher's individual experience.

In this specific teaching project designed to analyse and understand the social phenomenon under study, rather than simply presenting a list of historical events linked together by relations of cause and effect, the teacher begins the lesson by showing students the graphs illustrating the two statistical chronologies described in Figure 1 and 2, asking them to explain why – in their view – the two variables in question have changed over time. The teacher sets him/herself the goal of motivating students to identify the variables that played a key role in generating these trends, and in doing so gradually introduces the most significant historical events associated with these variables, taking care to describe the dynamics (behaviours) that these events have generated in the short, medium and long term. These brainstorming activities, carried out by the whole class as a group, are integrated with PowerPoint slides and an interactive whiteboard. The teacher arranges the content of the slides – the key variables identified by students – at random, and then stimulates them to describe the main relationships of cause and effect between the variables. These relationships will be represented graphically with red and blue arrows, where the blue arrow will represent a directly proportional relationship, while those in red an inverse relationship. This activity will produce as its final result a causal loop diagram similar to the one shown in Figure 3, which illustrates the key variables of the social phenomenon under analysis, the nature of their relationships and the main feedback loops that are assumed to be the basis of their behavioral trends.

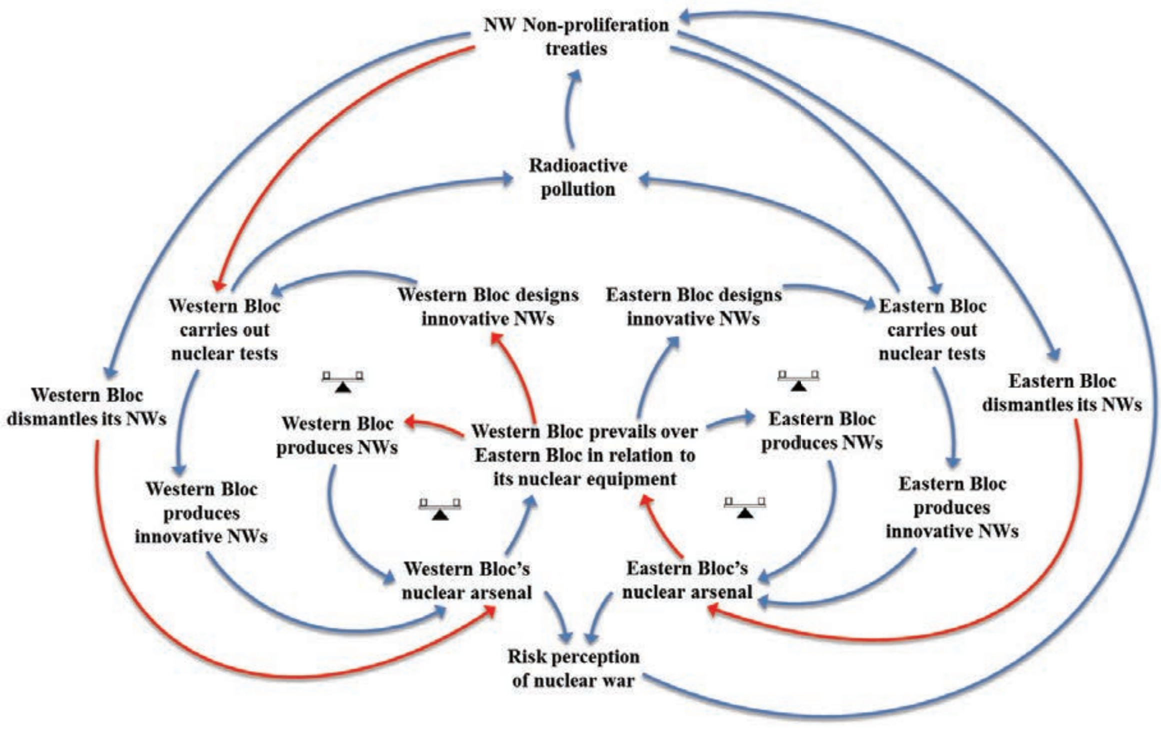

Figure 3. The Causal Loop Diagram describing the worldwide nuclear escalation phenomenon (NWs = Nuclear Warheads).

4.2.2 Creating cognitive dissonance.

As the key variables and their interrelationships are identified, the students begin to understand how the structure that is gradually being built requires them to consider variables and relationships (i.e. knowledge) to which they had not given any thought previously (Inch, 2002). At that point it will be very likely that these new findings conflict with their prior knowledge, which was elicited at the start of the teaching activity, thus generating the phenomenon of cognitive dissonance that will be addressed by the student with the help of the teacher and the entire class group.

4.2.3 Application of the knowledge with feedback.

The student then begins to understand that at the base of the historical phenomenon being analysed there is a complex map of variables that are interconnected in a complex way. The validity of this new schema (structure) for understanding and explaining the social phenomenon under study is verified both through simulation functions provided by the SD-based ILE and through the ability to generalize that pattern or structure, then applying the structure to other contexts or events of a social nature (Vermette et al., 2001; Windschitl, 2002). In this regard, the teacher stimulates students to trace regularities or "systemic archetypes" that underlie the social phenomenon observed, together with a variety of other social phenomena that are all quite different from each other (Senge, 1990). With regard to the phenomenon of nuclear escalation, one can trace two systemic archetypes that explain the dynamics of "Worldwide nuclear testing" and "Stockpiled warhead count": the first system archetype is called "escalation", the second "fixes that fail".

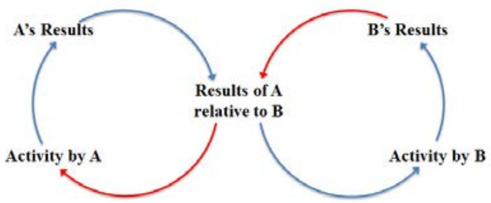

Figure 4. The structure of the "escalation" system archetype

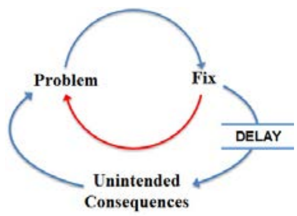

Figure 5. The structure of the "fixes that fail" system archetype

Senge (1990) describes the "escalation" system archetype as follows: "Two people or organizations each see their welfare as depending on a relative advantage over the other. Whenever one side gets ahead, the other is more threatened, leading it to act more aggressively to reestablish its advantage, which threatens the first, increasing its aggressiveness, and so on. Often each side sees its own aggressive behavior as a defensive response to the other's aggression; but each side acting "in defense" results in a buildup that goes far beyond either side's desires" (Senge, 1990). With regard to the "fixes that fail" archetype system, Senge (1990) says: "A fix, effective in the short term, has unforeseen long-term (delayed) consequences which may require even more use of the same fix".

The identification and understanding of the meaning of such system archetypes enables students to generalize their learning to other social phenomena. In this regard, the teacher could administer a test to verify what has been learned by expressly asking students to identify new social phenomena that could be explained by these same system archetypes.

4.2.4 Reflection on learning

Based on the CLD described earlier, students will be shown a stock and flow structure (simulation model) with the aim of observing the potential impact of some performance drivers on the behaviour of the considered social system. Through the analysis of the trends in key variables of the social system (phenomenon) in question, the student will have the opportunity to reflect on the scope and nature of what he or she has learned, and the fact that in the social sciences we are often faced with complex phenomena that require systemic thinking to be understood. The student will also have the opportunity to reflect on the fact that in complex social systems, variables with non-linear behavioural patterns are often observed. In addition, by using the simulation techniques called for by the SD-based ILE, the student will be able to understand the mechanisms that underlie the decision-making processes in contexts characterized by high complexity and uncertainty, including the time delays that characterize the cause and effect relationships between the variables involved.

By way of example, Figures 6 and 7 show some outputs produced by the SD-based ILE based on the assumptions of the simulation model and a hypothetical scenario (decision) evaluated by the student.

Figure 6 shows the Base Run scenario provided by the SD-based ILE, which faithfully reproduces the statistical chronology shown in Figure 2.

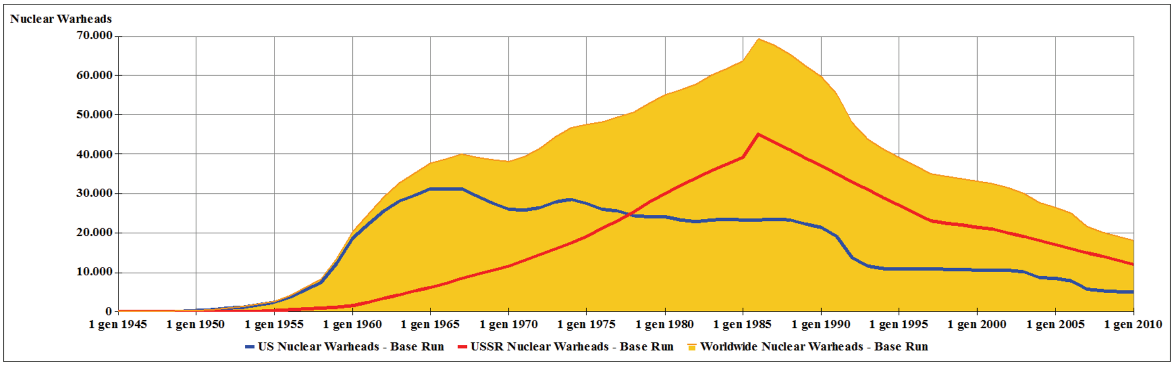

Figure 6. Stockpiled warhead count by year provided by the SD-based ILE (Base Run Scenario)

In figure 7, the Base Run Scenario and the Time Delay 10 yrs Scenario (Scenario A) have been compared in order to evaluate the potential effects of a reduction of the Time Delay of USA-USSR risk perception of nuclear war and radioactive pollution to 10 yrs on a system key-variable behaviour (in the Base Run Scenario the time delay is set to 17 yrs).

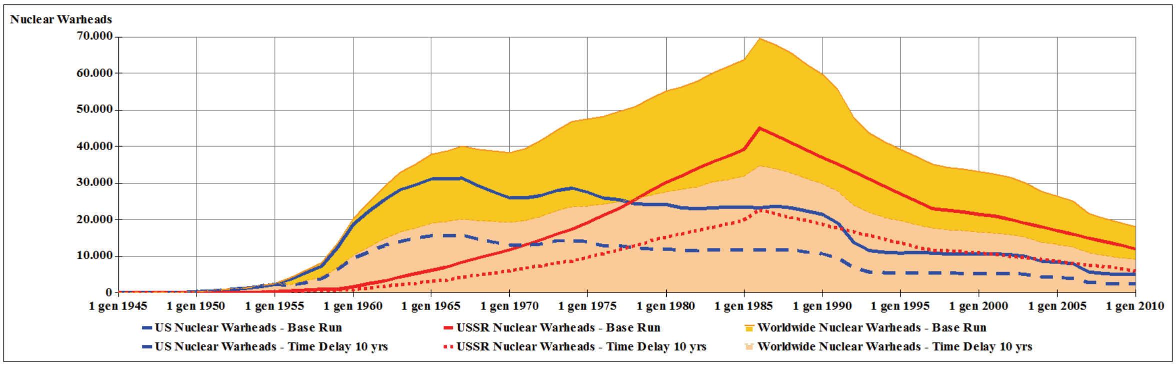

Figure 7. Stockpiled warhead count by year provided by the SD-based ILE – comparison of Base Run Scenario and Scenario A

It can be seen that the Time Delay 10 yrs Scenario shows a reduction in the stockpiled warhead count for both the US and the USSR.

4.3. The technological approach of the proposed ILE

System dynamics is a computer-aided approach to policy analysis and design that can be usefully applied to any dynamic system characterized by interdependence, mutual interaction, information feedback, and circular causality (Forrester, 1961, Sterman, 2000). The system dynamics approach aims to define problems dynamically and, by analysing the behaviour of the system variables over time, formulate both a qualitative model (called "causal loop diagram") capturing the feedback structure of the system and a quantitative model (called "stock and flow model") capable of reproducing, by itself, the dynamic problem of concern. Mathematically, the basic structure of a formal system dynamics computer simulation model is a system of coupled, nonlinear, first-order differential (or integral) equations,

$$\frac{d}{dt}x(t) = f(x, p) \tag{1}$$

where "x" is a vector of levels (stocks or state variables), "p" is a set of parameters, and "f" is a nonlinear vector-valued function.

5. Conclusions and further research.

As affirmed by Baviskar et al. (2009), constructivism can be translated into a teaching method provided that the four main constructivist criteria described above are met. The analysis carried out here seems to show that the educational activities that accompany the use of this SD-based ILE meet those criteria. It therefore seems that the proposed SD-based ILE can reasonably be defined as a constructivist teaching method.

Furthermore, as the use of this SD-based ILE assumes that the student is an active participant in the process of knowledge building, thanks to practical activities and simulation, this educational technology can also be considered a learner-centred teaching method.

One of the main limitations of this study is that the SD-based ILE proposed here has not yet been effectively implemented and used in a real teaching situation, and so it has not yet been possible to study its effects on student learning in the short, medium and long period, nor the effective capacity of this educational technology to promote the design and the actual implementation of meta-cognitive activities.

Future research will be aimed at assessing the effective capacity of SD-based ILE to support teachers in the process of integration of technological, pedagogical and content knowledge in their teaching of the social sciences.

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