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INTERPRETING THE CONCEPTS OF TECHNOLOGY-SOCIETY TO PUBLIC POLICY: THE POTENTIALS OF SYSTEM DYNAMICS AND COMPUTER GAMES

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Extended abstract

In this paper, we explore how Civilization, and – in a more general approach – computer games can enhance public administration (PA) education for interpreting technology-society concepts (or Science Technology Studies). We pose the research question, how computer games at the early stage of PA studies aligned with systematic curriculum design make educational experiences and the learning process more sensitised to system complexity, creativity and understanding the role of technology.

The paper shows an educational experiment where Sid Meier's Civilization series is used at the University of Public Service in Budapest. Civilization is one of the most famous turn-based strategy games, illustrating the complex causalities of economic development, geographical expansion, technology innovation, government structure and warfare. The players experience historical development through the ages of human Civilization – starting to build simple ancient huts to modern space exploration – and choosing different strategies to guide their Civilization through the challenges of allocating resources, managing conflicts, or deploying technological innovations. Civilization has been used in several classroom experiences for teaching history and complex system analysis.

Methodologically, we present an experiment ran at the University of Public Service in Budapest during the academic year of 2017–2018 written in a case study format. Our findings suggest promising results using computer games in four aspects of PA:

a) Effectiveness and efficiency of learning
We show that students have acquired the learning objectives – knowledge and skills – of technology-society relationships and system thinking effectively and efficiently. We show that the concept of Civilization has proven an effective method to demonstrate the comprehensive approach in PA – showing how the interplay of event, structure, and behaviour works on a grand scale.

b) Implications of advanced technologies in public administration studies
Our experiment has revealed that if students are presented with the historical contexts of technology and society relationship, their aptitude for the technology-society relationship becomes creative, sensitive, and opens up for appreciating the importance of public policies in the better functioning of governments.

c) Further applications of computer games (different uses of Civilization and others)
Based on the experiment, we developed recommendations on how computer and video games can be used in PA education. This is essential given our students' feedback, given the fact that the genre of PA education needs to be modernised for retaining astute talents for improving the future staffing of PA experts.

d) PA problems that can be solved by games: the reception of the idea
Finally, we have suggested ideas beyond the classroom learning for understanding complex PA problems by using simulation games based on our observations. 'Games' are the popularised versions of complex dynamic simulations of cause-effect relations that often reveal non-intuitive behaviour of systems, understanding of which is essential for future public leaders.

KEYWORDS:
Sid Meier's Civilization, system thinking, system dynamics, technology and society, computer games

1. INTRODUCTION

The broad church of Science-Technology Studies (STS) has investigated the complex duality of how technology shapes society and how social development either limits or triggers innovations. While a large amount of research contribution has shown the relevance of STS to conceptualise public policy challenges regarding technology innovations, such as in the cases of smart cities, e-participation, or the use of information communication technologies (ICT) in public services, it seems to be much more challenging to interpret STS constructs to actual policy planning and execution. Our research argues that a potential bridge connecting this theory-policy gap is the use of system dynamics and computer games – in part for modelling technology-society complexity and engaging future generations of public managers.

By putting system dynamics and computer games into the centre of our problem statement, we intend to investigate another challenge in public administration. That is the education of the present generation in colleges who will be employees, managers, decision-makers of administrative institutions – and beyond that – politicians, government members, representatives of collectives facing complex problems of our societies. The unique situation in STS is that they view the whole complexity through technology. Their perception of the world, access to information, processing experience, cognition and understanding is mediated in ubiquitous ICT, social media, and data abundance. However, very significantly, it is influenced by computer and video games of all kinds.

The conceptual – or theoretical – tension in public administration, especially in the Central Eastern European environment, is the conservative legal and political science tradition in practice and education. Even though ICT has been recognised and is even dealt with achieving progress in transforming administrative processes with ICT, future employees' philosophical mind setting is indoctrinated within traditional law, political science, or economics. System thinking, modelling and creative learning through the most familiar and comfortable media for the millennium generation is rare.

In this paper, we focus on this second issue by exploring how the application of computer games combined with system thinking and science-technology studies can enhance PA education and contribute to solving these educational challenges. We pose four research questions regarding how computer games at the early stage of PA studies aligned with systematic curriculum design make educational experiences and the learning process more successful than standard teaching and sensitise the millennium generation to the complexity of public policy decisions.

Firstly, we explore the effectiveness and efficiency of the learning process by applying a computer game. Secondly, we assess the implications of advanced technologies in public administration studies, especially how aptitude for the technology-society relationship becomes creative and opens up new approaches to public policies. Thirdly, we show how the existing genre of computer games can be used in PA education, and finally, we give an initial summary of what type of problems can be solved by games.

2. THE ROLE OF SCIENCE TECHNOLOGY STUDIES AND SYSTEM THINKING IN PA EDUCATION – A THEORETICAL AND CONCEPTUAL REVIEW

As a curriculum design experience at the University of Public Services in Budapest, two courses have been investigated. The University of Public Service (UPS) is responsible for educating the Hungarian public sector's future leaders and managers. UPS launched a five-year master program in Government Studies with the following objectives:

- educating its participants of the complex knowledge involving the tasks, organisation and operation of the state
- to provide skills and knowledge for systematically handling human capital and performing high-level planning, strategic analysis and leadership tasks
- to introduce the concept of strategic planning of public policy and analysis
- to make students capable of creating government models and understand the techniques, necessary legal and public service frameworks
- to familiarise students with the techniques of efficient management of the changes in state structure and governance
- to educate students on how to organise government activities using comparative methods and international models
- to introduce the societal, political, economic and human elements that define and influence government function

Technology and society-related questions are included in two courses within the program. An Information Society course introduces the cultural, political and economic issues of the information society and the Internet, reviewing the state responses to this challenge by analysing some information strategies. The course's strategic approach is emphasised by presenting the strategic incentives of the ICT companies, so it deals with network and microeconomic issues, as well as the macroeconomic impacts by which the information economy has an impact on national competitiveness.

Secondly, a 'Systems Theory and Analysis course' familiarises students with the basic terms of cause-effect relations, system thinking elements, and modelling complex legal, organisational and technological problems (positive and negative feedback, effects of delays and externalities, dynamic models, cause-effect diagrams). Students are supposed to acquire skills in exploring, analysing and evaluating basic system archetypes.

To methodologically enhance the two courses, we initiated a well-known turn-based strategy game series – Sid Meier's Civilization. Games, especially strategy simulation games, such as Civilization, are great tools to illustrate system complexity, how and why leaders allocate their resources, and, importantly, the impact of technology on social development and vice versa. During the gameplay of Civilization, we can observe how nations expand from ancient times due to economic development (see Figure 1), geographical expansion, warfare, and, most importantly, technology evolution.

Figure 1 • *Screenshot of Civilization VI – a modern city with special building and wonders (Source: Compiled by the authors.)*

In the case of the Information Society course, Civilization was used primarily to show the dynamic perspective of socio-technical evolution. In contrast, during the Systems Theory course, the game was applied for modelling and analysis.

3. SYSTEM DYNAMICS IN PUBLIC POLICY ESPECIALLY IN THE TECHNOLOGY-SOCIETY ANALYSIS: WHAT WE FIND IN SCOPUS

The two theoretical foundations of the experiment with students are Science-Technology Studies, or more precisely its interpretation of society-technology relationship, and system dynamics (SD) as a critical conceptualising and modelling framework. This second concept has originated from the groundbreaking work of Jay Forrester at MIT in the 1960s and still harnessing his heritage originating in 'urban and industrial dynamics' by his successors (for example, Donella Meadows, John Sterman, Peter Senge, and others), they expand the principles of SD into many different fields and applications from supply chain management, to sustainability and organisational development.

STS provides a rich platform to enhance the discourses of scientific and technological knowledge in socio-political contexts. Firstly, because STS has an operational standpoint, it is often referred to as an 'engaged program' assuming actions, creating conceptual and pragmatic positions.[1] Secondly, STS is inherently social and treats scientific and technological development as a complex social process, and considers that solutions/products of

[1] E Hackett, O Amsterdamska, M Lynch and J Wajcman, *The Handbook of Science Technology Studies* (Cambridge, MA: MIT Press, 2008).

these developments are not 'natural' by themselves.[2] This is especially relevant with information technology and information system applications since they are all created, programmed, designed by humans, where the 'sciences of the artificial' apply.[3] Furthermore, the third reason to embed this work into the STS domain is the broader context of politics and the role of governance at high and low levels to address the new digital world.[4] Scholars in the STS program have developed clear arguments that not only science and technology form politics and government, but, and this is probably a more critical direction, in this case, the political neutrality of science and technology is also questionable[5] – several technological paradigm changes have happened thanks to government interventions or even high-level political influences (space programs, the trickling effects of military technology, or even the Internet).

In Appendix 1, 2 and 3 we summarised what can be found in Scopus, running three keyword searches related to our problem statement and research question. Then the hits had been filtered for academic papers. In the first Table of the Appendices, those 'illustrative' papers are summarised, which until 2019 have had more than 50 references – therefore considered highly relevant contributions. I have also presented the annual trend of appearance, which is indicative of the increase of interest to publish in the researched topics. Finally, in order to get a first and high-level insight into the content differences between the three search results and the whole corpus of the 401 papers identified by the search of 'system dynamics, public policy, technology and society, and gaming', a word keyness analysis has been run using the abstracts of the papers. High-frequency words with a 95 per cent significance level ($p < 0.05$) of keyness are presented in the Appendices.

Appendix 1 contains the summary of 'system dynamics and public policy'; in the first Table showing the 17 most highly cited papers in SCOPUS out of the total 170 search results; scientific fields where most publications have found are sustainability, operations management, system thinking and energy. We can also see that the annual number of papers has grown from 2013 to an average of 10–15 papers from the earliest period of 5–7 papers in the 2000s showing interest in investigating how system dynamics is used in public policy.

Looking at the 'keyness' in the abstracts, we indicated the content and approach of these 170 articles. We got the confirmation that the main topics are environmental, sustainability and efficient energy utilisation. Interestingly, our problem is that we have not found significant key wording in policy analysis in administration, public affairs, or technology-society relationship. These publications seem to appear in the long tail of the 'public policy' search.

2 D Howcroft, N Mitev and M Wilson, 'What We May Learn from the Social Shaping of Technology Approach', in *Social Theory and Philosophy for Information Systems,* ed. by J Mingers and L Willcocks (Chichester: John Wiley & Sons, 2004), 329–371.

3 H Simon, *The Sciences of the Artificial* (Cambridge, MA: MIT Press, 1996).

4 C Perez, 'Technological revolutions and techno-economic paradigms', *Cambridge Journal of Economics* 34, no 1 (2010), 185–202.

5 L Winner, 'Do artifacts have politics?' in *The Social Shaping of Technology,* ed. by D MacKenzie and J Wajcman (UK: Open University Press, 1999), 28–40.

Appendix 2 summarises the keyword search combination 'system dynamics, technology and society'. We found nine papers out of the 156 with higher than 50 citations: naturally appearing in a different scientific field genre than the policy-oriented publications. However, sustainability and environmental orientation can be identified in this analysis as well. For instance, the Journal of Cleaner Production and the outlets in operations research and system dynamics seem to be highly relevant.

Keyness analysis of the 156 abstracts confirms the high dominance of environmentalist views in this search, as well. However, the words 'innovation' appearing 30 times and 'urban' 44 times indicate other directions as well in these papers.

We found the lowest number of results to search for 'system dynamics and gaming', summarised in Appendix 3. In this context, seven papers have over 50 references in SCOPUS out of the 75 total, and the main body of this literature has started to grow after 2005, yet this combination seems to be at its early stage. Keyness confirms this to some extent since these abstracts contain the highest number of significantly different wording (for brevity, we only included those words that appear more frequently than 10). It seems to be a convincing finding that amongst the highest and most significant wording, 'learning' is right in alignment with 'gaming', indicating that games go hand-in-hand with the individual, team and organisational learning. This research stream is being published in a different set of outlets than the previous two streams – simulation, management, modelling genres are much more frequent outlets in this group of papers.

Summarising the broad level exploratory keyword search in SCOPUS, we, therefore, can conclude that the system dynamics approach is a well-researched topic in the intersection of public policy, technology-society and gaming. By looking at the sheer number of articles and their timeliness, the interest and problem relevance is growing in these areas, and the theoretical background of the 'gaming and learning' – especially with computer games seems to be a promising direction for contributing to new findings in system dynamics application in technology-society areas. For exploring this, in the following section of the literature review, I turned to the questions of computer games and how Sid Meier's Civilization is used to learn system thinking.

The potential to use computer games in education has become relevant as its popularity and availability has grown. As the advancements in using video games and simulations for educational purposes in the corporate, government, and military worlds have grown, a similar change in the world of schools has raised.[6] With the appearance of serious games – games used for purposes outside of entertainment – a vast variety of opportunities have risen.[7] For instance, Squire (2008) uses an overview of two games-based research programs in education to make a case for a gaming-based future of education through the specific use of commercial games or gamification and gaming techniques.

[6] D W Schaffer, K R Squire, R Halverson and J P Gee, 'Video Games and the Future of Learning', *Phi Delta Kappan* 87, no 2 (2005), 105–111.

[7] T Susi, M Johannesson and P Backlund, *Serious Games – An Overview.* Technical Report HS- IKI -TR-07-001, 28, 2007.

Another literature review summarises the effect of video games on students at the age of 14 years, finding links of numerous cognitive and other outcomes; the most common of which was the acquisition of knowledge and motivational outcomes.[8]

Civilization is one of the oldest and most widely known turned-based strategy games in the gaming industry. Its use in classrooms has been explored mainly in history education, for instance, discussing how good the game is to effectively study alternate historical events.[9] Pagnotti and Russell III (2012) explore the use of a specific lesson plan using Civilization IV to teach world history to ninth-grade students in the hope of encouraging high-order thinking. As Wainwright (2014) reports after experimenting with the 4th edition of the game series, student feedback indicates that the methods used allow many undergraduates to better understand complex historical concepts and form assumptions based on critical analysis of the historical context of the game. It also helps children learn visual conceptualisation.[10] Using Civilization in the classroom is fun; research proves that the enjoyment factor overrules the conceptual scaffolding, indicating that free flow and creativity are essential when video games are deployed in education.[11]

Computer games are also used in PA and related fields. For instance, noteworthy applications are documented by Kolson (1996) using SIM CITY or Mayer (2009) to use games in politics. There are also proposals on how to conceptually integrate games in civil service education.[12] Civilization is used to learn about power games, and Valdre (2007) claims that players of Civilization through their play, get used to various theoretical tools, such as the concept of cultural, social and economic capital, and how they influence modern social practices and learning processes.

Methodologically, most research in the field uses case study based approaches similar to Watson et al. (2011), who also give a detailed guideline designing and executing research of this kind.

4. RESEARCH METHODOLOGY

Before starting the Information Society course at the first session, we surveyed students to form an image of their experience as gamers, their specific experience with strategy video games or the Civilization series in particular, and the level of their digital literacy in a general sense. Based on the information obtained, we organised the volunteers into groups of 3 or 4

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8 T M Connolly, E A Boyle, E MacArthur, T Hainey and J M Boyle, 'A systematic literature review of empirical evidence on computer games and serious games', *Computers & Education* 59, no 2 (2012), 661–686.

9 A Burns, 'Civilization III: Digital game-based learning and macrohistory simulations', 2002.

10 C-C Liu, H S Chen, J-L Shih, G-T Huang and B-J Liu, 'An enhanced concept map approach to improving children's storytelling ability', *Computers & Education* 56, 3 (2011), 873–884.

11 D Charsky and W Ressler, '"Games are made for fun:" Lessons on the effects of concept maps in the classroom use of computer games', *Computers & Education* 56, 3 (2011), 604–615.

12 C Raphael, C Bachen, K-M Lynn, K McKee and J Baldwin-Philippi, 'Games for Civic Learning: A Conceptual Framework and Agenda for Research and Design', *Games and Culture* 5, no 2 (2010), 199–235.

members, which we would be sure to balance out in terms of player experience. The groups' controlled division was meant to avoid specific teams getting a clear advantage over the others that would have made the game experience seem unfair. Table 1 depicts how students assessed their skills and willingness to join the gaming seminar on a 1 (worst) to 4 (best) scale.

Table 1 • *Students' skills in digital literacy and gaming – Kahoot survey before the experiment (Source: Compiled by the authors.)*

		DigiLit	Games	StratGames	Civ	Willingness
N	Valid	97	97	97	97	97
	Missing	0	0	0	0	0
Mean		2.49	2.76	2.07	1.58	2.61
Minimum		0	0	0	0	0
Maximum		4	4	4	4	3

Students perceived their digital literacy skills lower than experience with computer games, but knowledge of strategy games and particularly Civilization had been the lowest. It is important to underline what Table 2 shows about correlations between these variables. Willingness to participate in the gaming experiment was only moderately correlating with the experience of using Civilization earlier (Spearman rho = 0.269, $p > 0.99$), and we only found medium-strong correlations between gaming, strategy gaming and Civilization use after the non-parametric correlation test (see Table 2). We found it slightly surprising that the perceived assessment of digital literacy and gaming experience did not correlate with the willingness to learn the course by playing Civilization. We assume that the main reason for this had been the uncertainty of the new method and the requirements which had been only easily attainable to those who had experience in computer games.

After the second semester, our assumption was verified when students enrolled in the System Theory course, and the Civilization bases seminar was offered to continue. As we can see in Table 3, during the first semester in the Information Society course, we could form 7 groups with 19 students. During the second term, the number of students grew to 35, which we organised into 13 groups. Correlation tests have not shown any difference between these groups in gender or any other variable.

Courses would be held on a weekly or bi-weekly basis. This would give us a set of regular opportunities to play the game as a group and discuss possible difficulties that arise throughout the semester. The sixth game in the series, Civilization VI, would be the version used in the classroom, but any of the previous games would be used at home. Limitations of the computer hardware at our disposal meant that the latest game in the civilization series, Civilization VI, was not a reasonable choice. The chosen version then became Civilization IV, the latest of the games that would reliably run on our systems and receive some of the best critical acclaims. During the classes, the game would provide simulated examples useful in helping the student grasp the otherwise theoretical concepts in practice.

Table 2 • *Correlation between digital literacy, gaming experience and willingness to participate (Source: Compiled by the authors.)*

			DigiLit	Games	StratGames	Civ	Willingness
Spearman's rho	DigiLit	Correlation Coefficient	1,000	,246*	**,334****	**,296****	,170
		Sig. (2-tailed)	.	,015	**,001**	**,003**	,096
		N	97	97	**97**	**97**	97
	Games	Correlation Coefficient	,246*	1,000	**,419****	**,559****	,087
		Sig. (2-tailed)	,015	.	**,000**	**,000**	,394
		N	97	97	**97**	**97**	97
	StratGames	Correlation Coefficient	,334**	,419**	1,000	**,567****	,226*
		Sig. (2-tailed)	,001	,000	.	**,000**	,026
		N	97	97	97	**97**	97
	Civ	Correlation Coefficient	,296**	,559**	,567**	1,000	**,269****
		Sig. (2-tailed)	,003	,000	,000	.	**,008**
		N	97	97	97	97	97
	Willingness	Correlation Coefficient	,170	,087	,226*	,269**	1,000
		Sig. (2-tailed)	,096	,394	,026	,008	.
		N	97	97	97	97	97

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 3 • *Group distribution by semesters and genders (Source: Compiled by the authors.)*

	S1Group (Semester 1) Information Society							S2Group (Semester 2) System Theory												
Group Number	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10	11	12	13
Male	2	2	3	0	2	2	0	2	1	2	0	2	3	1	3	1	3	2	0	1
Female	1	1	1	1	1	2	1	0	2	0	3	1	0	2	0	2	0	0	3	1

The first class in the Information Society course would be dedicated to introducing the game Civilization IV itself. For this purpose, a short clip was created by the third author of our paper and published online to familiarise students with the game's significant concepts (Figure 2). After assigning the students to their respective groups, we would begin teaching them the primary game mechanics, making sure that by the end of the first class, they would possess all knowledge necessary to initiate, save and load their games, to issue commands to their units, manage the production cues of their cities, assign technologies to research, and be able to find any additional relevant information on their own if need be. Assignments would be handed out via the e-learning systems in between classes.

A second class would be scheduled halfway through the semester to provide the students an opportunity to address any concerns that arise along the way in person. Additionally, if time permitted, this class would also be used to start a multiplayer game session, where the groups would play competitively against each other – practicing particular techniques connecting to the course material focused on the technology tree and exploring technology, focusing on decisions, causality, teamwork and generalisation.

Figure 2 • *Introductory video prepared by the authors to demonstrate the basics of the gameplay (Source: www.youtube.com/watch?v=bii4hNBtGCI)*

The third and final class would be dedicated to discussing the completed tasks and reflecting on the semester using a group interview format. The discussion would also focus on gathering feedback to judge the program's overall effect and identify areas to improve.

Over the semester, the groups would document the games they played and the tasks they completed in journals. These would contain the significant decisions made during their gameplay, the reasoning and thought processes, and their effects on the outcome compared and contrasted to their expectations. Solutions and answers to the assigned tasks and, optionally, any desired feedback would also be included in these journals.

The second semester of the course was different in many ways. Some of the limitations on us in the first semester were not present this time, and we also made several changes based on feedback gathered from the students on our last session. The bi-weekly sessions became a reality this time. During the lecture hours, a computer laboratory was made available, allowing us to organise regular sessions. A key difference was a much closer collaboration with the lectures and the assignments' connection with the topics presented during the lectures. Conceptually, the System Theory class's gaming sessions used Civilization as an illustration for the topic, starting with a presentation followed by team discussion and summarising the previous and the upcoming home assignment.

The first class had little difference compared to Information Society: students played Civilization, and newcomers had to familiarise themselves with the game mechanics. Topics of the second class were system attributes and system control. The third modelling was discussed along with organisational use: students had to play with 'Stanley's Parable' to demonstrate system models' limitations and apply flowcharts.

The fourth class dealt with system dynamics; students were introduced to the 'beer game' and the 'Surviving Mars' simulation. In the fifth class, MIT's Moral Machine was brought in, and topically students discussed decision-making, which was further extended in the sixth session with complex networks. Here two new games were introduced: Democracy 3 and Europa Universalis. Finally, in the last class, the topic of scale-free networks was covered: here, we returned to using Civilization.

In between classes, students would be assigned tasks involving further gameplay to complete with their group.

Group assignments were restructured to feature a task list with individual point amounts assigned to each sub-task to allow the students an easier understanding of each element's weight. We also decided to allow the students to form groups based on their choice. This was done based on the students' feedback, where group dissonance was the most common difficulty experienced. New players were more likely to learn the game well if they worked together with others they were comfortable with, regardless of the other players' skills. Groups were only formed by us in such cases where students did not form groups of their own or did not have enough members. It is worth mentioning that these were freshmen students who did not yet know each other well in the first semester.

The end would be a log of the events that occurred in the sessions, with specific attention dedicated to answering questions posed by the teachers.

5. DISCUSSION OF RESULTS

In Table 3 we summarise the number of students who provided feedback on their learning experience. Altogether, from the 54 students who acquired the material of the two semesters by using the Civilization game experience, 49 responded.

Table 4 • *Group distribution by semesters and genders (Source: Compiled by the authors.)*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not played	77	61.1	61.1	61.1
	Played	49	38.9	38.9	100.0
	Total	126	100.0	100.0	

In the following discussion section, we give a general summary of these reports, observations and juxtaposition of other sources such as colleagues' opinions.

5.1. Effectiveness and efficiency of learning

Attendance of classes varied considerably between the first and second semesters. Requirements were different; while in the first term, grades were given only based on the homework submission, class attendance was not required for all the sessions; only two of them had been mandatory. After concluding, we required at least one team member to attend the seminars and the lectures. Interestingly, the 24 seated Computer Lab occasionally proved to be too small, and extra places needed to be created.

The 7 Study Groups during the first semester of the Information Society course reported that they enjoyed playing the game and working on the exercises. However, they did not value the content any higher than the lectures. From the course assessments, our students had a great time in the first semester but did not get much new information from our alternate method, and they gain most of the subject's content from the lectures. During the second semester, the 13 Study Groups, although still enjoyed the gameplay, had to work on more assignment topics that were more tightly connected to the topics of the lectures in System Theory.

The following basic knowledge concepts have been the learning objectives of the two programs:

Information Society

- to understand the impact of technology on society and how technology development is impacted by social developments
- technological determinism and diffusion theory
- Gartner's Hype cycle
- Social Construction of Technology and technorealism

System Theory

- system approach, system attributes, target predicates and decision-making attributes
- complex cause and causal loop diagrams, modelling, participation modelling
- supply-chain management, flowcharts, Critical Path Method and principles of process mapping
- basics of system dynamics and team dynamics

In summary, the students had to acquire the viewpoints and methodological frameworks of system analysis and the technology-society relationship. The key objective was to convey a comprehensive approach to study PA and understand how structure determines behaviour and results in specific events. Students' feedback on the learning experience is summarised in Table 5.

Apart from the learning experience, those how had chosen the Civilization gameplay valued easiness acquired knowledge better, and their class attendance was also more frequent (a grey area in Table 5). However, if we take a closer look at these differences – depicted in the lower sections of Table 5 – we see that those 18 students who took the Civilization seminars in both semesters (variable Both) did value all four questions higher than those students who took only one Civilization seminar or none. There might be several explanations for these variations, some of them could be the uncertainty at the beginning of the Information Society course, some – especially in the second semester – the lower willingness to attend classes (there is a drop from 8.5 to 6.36). Simultaneously, the easiness was assessed gradually higher (first semester 6.5, second semester 9.00 while the two together 9.29). However, what is very promising is that knowledge acquisition seems to be consistently viewed more effectively with the Civilization seminar than amongst those students who had not taken that path. Unfortunately, with this sample, we were not able to conclude more. The difference has not proven significant by any means testing variation, so our case did not prove that this difference is not random.

Table 5 • *Students' feedback on the learning experience is categorised by participation (Source: Compiled by the authors.)*

			Experience	Easiness	Knowledge	Attendance
CIV_Played	Not played	Count	77	77	77	77
		Mean	8.03	8.52	6.14	6.86
		Standard Deviation	2.08	1.57	2.25	2.66
	Played	Count	49	49	49	49
		Mean	7.78	8.87	6.83	7.09
		Standard Deviation	2.94	1.22	2.19	2.19
Participation	Regular	Count	77	77	77	77
		Mean	8.03	8.52	6.14	6.86
		Standard Deviation	2.08	1.57	2.25	2.66
	Infosoc	Count	10	10	10	10
		Mean	7.50	6.50	6.50	8.50
		Standard Deviation	.71	2.12	.71	2.12
	Sysanal	Count	21	21	21	21
		Mean	7.57	9.00	6.86	6.36
		Standard Deviation	3.65	.96	2.38	2.34
	Both	Count	18	18	18	18
		Mean	8.29	9.29	6.86	8.14
		Standard Deviation	1.50	.76	2.27	1.35

We get more insight into students' perceptions if we analyse their written comments about two questions: a) description of substantial knowledge and skill areas acquired during the course; and b) sharing any comment about the course, both positive and negative. Table 6 shows the keyword analysis results using the responses from the first set of answers, and Table 7 shows the keywords from the second. For the analysis, we used AntConc 3.4.4., a freely available but robust multiplatform tool for carrying out corpus linguistics research and data-driven learning, developed by Anthony Laurence at the Faculty of Science and Engineering at Waseda University in Japan.

The keyword analysis has been executed in two steps. Firstly, we created a text corpus from the students' responses about the two topics – the first file consisted of 450 words (on the knowledge content of the course). The second consisted of 559 words (on the experience being in the course). These two lists then were used as the keyword list range, or as a corpus reference, compared to which I calculated the so-called keyness variable for the three groups of students – who took the regular sessions (Regular), who only took part in the information society course (Infosoc), and who took part in the system theory class (Sysanal). The analysis goes beyond a simple word count since it shows which words are unusually frequent (or infrequent) compared to the words in a reference corpus. This allows us to identify characteristic words – hopefully unique to the three student groups.

Table 6 • *Keyword analysis of students' response to concrete knowledge areas they learned (Source: Compiled by the authors.)*

	W.c.	Keyness	Regular		W.c.	Keyness	Infosoc		W.c.	Keyness	Sysanal
1	94	13.116	was	1	4	3.163	game	1	3	4.429	which
2	22	8.937	enjoyable	2	5	3.140	about	2	3	3.485	box
3	36	8.817	lectures	3	3	2.372	civ	3	3	3.485	these
4	14	5.687	only	4	4	2.370	different	4	6	3.055	we
5	14	5.687	opinion	5	6	2.139	many	5	2	2.953	applicable
6	50	5.344	more	6	7	1.939	things	6	2	2.953	network
7	12	4.874	found	7	3	1.611	has	7	3	2.759	most
8	12	4.874	Kahoot	8	2	1.581	civilization	8	2	2.067	elements
9	12	4.874	one	9	2	1.581	essential	9	2	2.067	help
10	12	4.874	teacher	10	2	1.581	helps	10	2	2.067	helped
11	12	4.874	them	11	2	1.581	lot	11	2	2.067	liked
12	12	4.874	there	12	2	1.581	managing	12	2	2.067	really
13	24	4.740	good	13	2	1.581	see	13	3	1.725	decision
14	24	4.740	would	14	2	1.581	semester	14	5	1.478	what
15	10	4.062	attend	15	2	1.581	significance	15	1	1.476	analysed
16	10	4.062	difficult	16	4	1.279	decision	16	1	1.476	became
17	10	4.062	like	17	6	1.057	this	17	1	1.476	causes
18	10	4.062	somewhat					18	1	1.476	choice
19	8	3.250	attending					19	1	1.476	choices
20	8	3.250	basically					20	1	1.476	components

Keyness is calculated using the Log Likelihood method.[13] When using either Log Likelihood or Chi-squared as the statistical measure, the following significance values apply:

– 95th percentile; 5% level; $p < 0.05$; critical value = 3.84
– 99th percentile; 1% level; $p < 0.01$; critical value = 6.63
– 99.9th percentile; 0.1% level; $p < 0.001$; critical value = 10.83
– 99.99th percentile; 0.01% level; $p < 0.0001$; critical value = 15.13

Taking this into consideration, in Table 6 we can see that the keyness of listed 14 words for the regular group is significant on a 5 per cent level, and two relevant words 'lectures' and 'enjoyable' on a 1 per cent level. All these words show a positive assessment of the whole course, 'teacher' is very relevant since the second semester and the excellent professor ran the lectures who used 'Kahoot' exercises at the end of each session. In the other two categories, we mostly see conjunctions and pre-positions on any significant level.

13 P Rayson, 'From keywords to key semantic domains', *International Journal of Corpus Linguistics* 13, no 4 (2008), 519–549.

However, the word count column indicates the frequency of the unique phrases in each group. These – not significantly, though – express the difference using words like 'Civ, game, Civilization', and 'applicable, network, elements', and so on.

Table 7 • *Keyword analysis of students' response to learning experience during their courses (Source: Compiled by the authors.)*

	W.c.	Keyness	Regular		W.c.	Keyness	Infosoc		W.c.	Keyness	Sysanal
1	13	2.248	lectures	1	6	2.521	tasks	1	4	4.606	using
2	6	2.015	teacher	2	4	1.681	all	2	8	3.253	more
3	15	1.429	subject	3	4	1.681	been	3	5	2.839	enjoyable
4	4	1.343	assignment	4	4	1.681	civ	4	2	2.783	decision
5	4	1.343	basically	5	5	1.469	assignments	5	2	2.783	games
6	4	1.343	exam	6	5	1.469	from	6	2	2.783	impression
7	4	1.343	his	7	5	1.469	game	7	2	2.783	talking
8	4	1.343	lecturer	8	3	1.261	into	8	2	2.783	these
9	4	1.343	no	9	3	1.261	previous	9	2	2.783	you
10	24	1.284	was	10	3	1.261	will	10	4	2.186	my
11	3	1.007	am	11	4	1.069	alternative	11	2	1.913	about
12	3	1.007	experience	12	4	1.069	way	12	2	1.913	life
13	3	1.007	fair	13	28	1.043	to	13	2	1.913	most
14	3	1.007	humour					14	4	1.468	would
15	3	1.007	liked					15	1	1.391	aspects
16	3	1.007	overall					16	1	1.391	beer
17	3	1.007	than					17	1	1.391	ber

When in Table 7 we examine the keyness indicators for the students' experience – a general opinion about how they had felt during the courses – we find similar words in the regular cohort. However, none are significant 'key'. The situation is the same when we look at the Infosoc and Sysanal columns with quite many words describing the typical genres of the different experiments. After running a concordance analysis with the four occurrences of the only one crucial keyword 'using', we confirmed that three of these were reflecting the instructor's skills to use Kahoot, compelling examples, and the famous beer game, and only one referred to the use of gaming and related exercises. Running concordance analysis with the 2nd most frequent word, 'enjoyable', it became apparent that the second semester System Analysis course was highly rated because it was better organised. There were more team assignments, and students could choose more options for meeting requirements.

5.2. Technologies

Civilization models the impact of technology on society by using the 'technology tree'. Players choose how they climb this tree; that is, in what sequence they explore and deploy new technological innovations. To facilitate discourses on the complex technology-society relationships, we asked our students to discuss interesting technologies and their potential impact on society. The recommended technologies were included.

5.2.1. Space technologies, new materials, cloning (future based)

– *Cloning and Genetic modification:* For improvements in military and population control and increasing the quality of life.
– *Extra-terrestrial bases:* To add the ability to construct bases on other astral bodies for a considerable boost to scientific research, as well as a significant increase in resources.
– *Terraforming:* To create resource deposits on the map and help shape the terrain to choose the player.
– *Wormhole theory:* This allows fast travel between planets.
– *Alternative energy sources:* Effects the populations' happiness to reflect the reduced environmental impact.

5.2.2. Information communication technologies (present, mainstream)

– *Nanotechnology:* For use in improving medical procedures and furthering scientific research capabilities.
– *Artificial intelligence:* To improve the effectiveness of mechanical units.
– *Automated vehicles:* Helps to improve the effectiveness of trade and economic growth.
– *3D printing:* Helps to reduce production costs in cities, provides cultural and happiness increases.
– *LED technology:* To reduce the power consumption of electronic devices, increasing happiness and reducing upkeep costs.
– *Retinal scanners:* To help provide an extra measure of defence for keeping researched technologies safe from foreign espionage.
– *Drone technology:* Improves military capabilities and surveillance at the cost of a negative impact on happiness.

5.2.3. Socio-technical concepts

– *Social networking:* Effects of population growth and the spread of culture.
– *Virtual reality:* For use in better training military units, with added cultural and entertainment values.
– *Universal translation technology:* An essential tool in aiding relations with external civilizations.
– *International sports events:* Helps to increase the population's health by promoting sports and exercise and providing cultural bonuses to hosting countries.

5.3. Further applications of gaming

To collect suggestions from students based on their experiences both with computer games and with their government studies, we asked them which other video games they believe could be used for other educational purposes in their program. The following is the summation of the recommended games and areas:

To better understand strategical thought processes and other similar functions, many of the students recommended the use of other well renowned *grand-strategy games* such as Crusader Kings (Figure 3), Europa Universalis, or Hearts of Iron.

Figure 3 • *Crusader Kings – grand strategy game illustration (Source: Compiled by the authors.)*

Various MMORPGs *(Massively Multiplayer Online Role-Playing Games),* such as World of Warcraft and Eve Online (Figure 4), were recommended to help depict a single individual's role within a sizeable coherent system.

Figure 4 • *Eve Online – MMORPG illustration (Source: Compiled by the authors.)*

Several students recommended CCGs *(Collectable Card Games)* to showcase the importance of risk management, that is, how to utilise the tools under our control to cope with random occurrences within the system. We show a set of these in Figure 5.

Figure 5 • *Collectible Card Game illustration (Source: Compiled by the authors.)*

The various games in the *city builder game series* Sim City (Figure 6) were recommended for use in showcasing causality, the effects that elements of a system can have on the others, and how to create models and diagrams of the process. The Sim City games' tendency to showcase city information in graphs and charts was also a reason to suggest these games to improve data interpretation abilities. Other city builder games were also mentioned for this purpose, such as Banished or Zeus and Poseidon.

Figure 6 • *Sim City – city builder illustration (Source: Compiled by the authors.)*

The MMORPGs mentioned above were also commonly grouped with *team-based tactical action games,* such as DOTA 2 (Defense of the Ancients) (Figure 7) or Heroes of the Storm, to train in team structuring and communication.

Figure 7 • *Dota-2 – team-based tactical action illustration (Source: Compiled by the authors.)*

Numerous games of different genres were mentioned to help understand system characteristics and the ways to control and influence them. *Real-time strategy games* recommended here included Age of Empires, Starcraft and the Total War series. *Survival/crafting games* recommended included titles like Rust, Space Engineers and Minecraft – illustrations are shown in Figure 8.

Figure 8 • *Ages of Empires and Space Engineers – real-time strategy and survival game illustrations (Source: Compiled by the authors.)*

5.4. PA Problems that can be solved by games: the reception of the idea

Beyond the two particular courses' learning objectives, students reported other – more general – impacts of the experiment. The groups consisting of three members were introduced to develop teamwork and reflect in the journals on how they identified key decision points, assessed alternatives, and had come to joint decisions. They reported several learning conclusions and also how these exercises encouraged creativity.

After the course, we received feedback that it is easier to connect cause-and-effect relationships between the various legal areas and grasp how society is impacted as an organic system. This is especially important in central and eastern European PA education, which is traditionally employed only in law and often handles the different legal areas separately, barely touching technology's influence on administrative thinking.

Thanks to our acquired experience and the students' critical feedback, our methods during the Systems Theory course in the second semester became much more refined. Due to this, our alternative opportunity for course completion became a bolder, more extensive rival to the traditional 'lecture path'. Education of the subject proceeded along with the same goals as before: the broad expansion of PA skills through the use of our method while still teaching the material in the curriculum in an enjoyable fashion.

6. CONCLUSION

System Analysis and Thinking subjects with Information Society topics in PA education help future leaders understand our societies' complexities in the 21st century.

In the reported experiment at UPS, we tested the use of the turn-based strategy game Civilization to identify the effects of technology on society and individuals so that students become more foresightful and empathetic in the future of their choice. Information Society also emphasises the importance of Systems Theory as shown by the university in the course description. However, to demonstrate this to students, it is not enough to illustrate how culture and technology affect each other in an information society or what processes occur within society as a system – they must also understand how these dualities work. That is where our experiment's main contribution lies, especially with the deployment methods and practical tools presented to students. Participating students reported that putting technology and complex system thinking with using strategy simulation concepts at the beginning of their Government Studies program raises awareness and the experience factor of their education.

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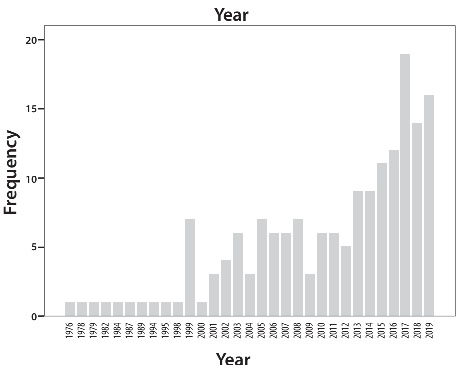
Appendix 1. Top cited papers; word keyness in abstracts; frequent journals, yearly publications – System dynamics and Public Policy

Authors	Title	Year	Source title	Volume	Issue	Page		Cited by
Bergek A., Jacobsson S., Carlsson B., Lindmark S., Rickne A.	Analyzing the functional dynamics of technological innovation systems: A scheme of analysis	2008	Research Policy	37	3	407	429	704
Vlachos D., Georgiadis P., Iakovou E.	A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains	2007	Computers and Operations Research	34	2	367	394	252
Oliva R., Sterman J.D.	Cutting corners and working overtime: Quality erosion in the service industry	2001	Management Science	47	7	894	914	230
Oliva R.	Model calibration as a testing strategy for system dynamics models	2003	European Journal of Operational Research	151	3	552	568	138
Johansson D.J.A., Azar C.	A scenario based analysis of land competition between food and bioenergy production in the US	2007	Climatic Change	82	March	267	291	132
Ghaffarzadegan N., Lyneis J., Richardson G.P.	How small system dynamics models can help the public policy process	2011	System Dynamics Review	27	1	22	44	126
Georgiadis P., Vlachos D., Iakovou E.	A system dynamics modeling framework for the strategic supply chain management of food chains	2005	Journal of Food Engineering	70	3	351	364	124
Galanakis K.	Innovation process. Make sense using systems thinking	2006	Technovation	26	11	1222	1232	111
Gary M.S.	Implementation strategy and performance outcomes in related diversification	2005	Strategic Management Journal	26	7	643	664	84
Kollikkathara N., Feng H., Yu D.	A system dynamic modeling approach for evaluating municipal solid waste generation, landfill capacity and related cost management issues	2010	Waste Management	30	11	2194	2203	76
Dangerfield B.C.	System dynamics applications to european health care issues	1999	Journal of the Operational Research Society	50	4	345	353	69
Zhang X.H., Zhang H.W., Chen B., Chen G.Q., Zhao X.H.	Water resources planning based on complex system dynamics: A case study of Tianjin city	2008	Communications in Nonlinear Science and Numerical Simulation	13	10	2328	2336	60
Dutta A., Roy R.	Offshore outsourcing: A dynamic causal model of counteracting forces	2005	Journal of Management Information Systems	22	2	15	35	57
Liu X., Mao G., Ren J., Li R.Y.M., Guo J., Zhang L.	How might China achieve its 2020 emissions target? A scenario analysis of energy consumption and CO2 emissions using the system dynamics model	2015	Journal of Cleaner Production	103		401	410	55
Abbas K.A., Bell M.G.H.	System dynamics applicability to transportation modeling	1994	Transportation Research Part A	28	5	373	390	55
Forrester J.W., Mass N.J., Ryan C.J.	The system dynamics national model: Understanding socio-economic behavior and policy alternatives	1976	Technological Forecasting and Social Change	9	January	51	68	51

Rank	Freq		Keyness	Effect	Keyword	Rank	Freq		Keyness	Effect	Keyword
1	**302**	**+**	**66.19**	**0.0182**	**policy**	16	50	+	5.68	0.0031	elsevier
2	**149**	**+**	**28.49**	**0.0091**	**policies**	17	47	+	5.47	0.0029	demand
3	**116**	**+**	**23.84**	**0.0071**	**public**	18	17	+	5.46	0.001	participatory
4	54	+	12.95	0.0033	carbon	19	25	+	5,08	0.0015	green
5	72	+	9.95	0.0044	market	20	304	+	4,7	0.0182	that
6	67	+	9.53	0.0041	government	21	58	+	4.69	0.0036	scenarios
7	42	+	8.89	0.0026	population	22	13	+	4.67	0.0008	fit
8	55	+	8,11	0.0034	emissions	23	13	+	4.67	0.0008	rps
9	47	+	7.55	0.0029	waste	24	26	+	4.55	0.0016	emission
10	33	+	7,28	0.002	price	25	12	+	4.31	0.0007	cap
11	37	+	7,24	0.0023	renewable	26	12	+	4.31	0.0007	fcvs
12	26	+	6.91	0.0016	food	27	12	+	4.31	0.0007	hilsa
13	31	+	6.61	0.0019	co	28	12	+	4.31	0.0007	offshoring
14	302	+	6.46	0.0181	model	29	12	+	4.31	0.0007	pension
15	26	+	5.88	0.0016	sectors	30	28	+	4,02	0.0017	limited
						31	11	+	3.95	0.0007	poverty

Journal of Cleaner Production
Journal of the Operational Research Society
System Dynamics Review
Systems Research and Behavioral Science
Resources, Conservation and Recycling
Energy
Energy Policy
European Journal of Operational Research
Journal of Construction Engineering and Management
Kybernetes
Xitong Gongcheng Lilun yu Shijian/System Engineering Theory and Practice

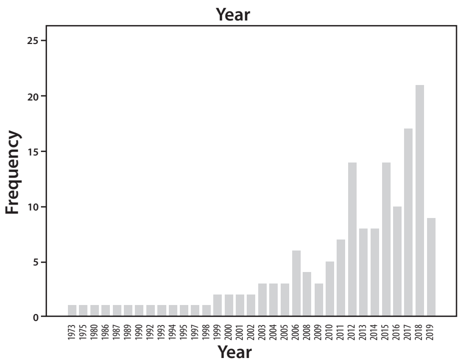


Appendix 2. Top cited papers; word keyness in abstracts; frequent journals, yearly publications – System dynamics and Technology and Society

Authors	Title	Year	Source title	Volume	Issue	Page		Cited by
Garud R., Kumaraswamy A.	Vicious and virtuous circles in the management of knowledge: The case of Infosys Technologies	2005	MIS Quarterly: Management Information Systems	29	1	9	33	220
Hilty L.M., Arnfalk P., Erdmann L., Goodman J., Lehmann M., Wäger P.A.	The relevance of information and communication technologies for environmental sustainability - A prospective simulation study	2006	Environmental Modelling and Software	21	11	1618	1629	168
Otto A., Kotzab H.	Does supply chain management really pay? Six perspectives to measure the performance of managing a supply chain	2003	European Journal of Operational Research	144	2	306	320	158
Richardson G.P.	Reflections on the foundations of system dynamics	2011	System Dynamics Review	27	3	219	243	131
Verhoef E.V., Dijkema G.P.J., Reuter M.A.	Process knowledge, system dynamics, and metal ecology	2004	Journal of Industrial Ecology	8	January	23	43	85
Van Vuuren D.P., Strengers B.J., De Vries H.J.M.	Long-term perspectives on world metal use-a system-dynamics model	1999	Resources Policy	25	4	239	255	82
Alipour S., Mehboudi M., Rezakhani A.T.	Quantum metrology in open systems: Dissipative cramér-rao bound	2013	Physical Review Letters	112	12			80
Marshall D.A., Burgos-Liz L., Ijzerman M.J., Osgood N.D., Padula W.V., Higashi M.K., Wong P.K., Pasupathy K.S., Crown W.	Applying dynamic simulation modeling methods in health care delivery research - The SIMULATE checklist: Report of the ISPOR simulation modeling emerging good practices task force	2015	Value in Health	18	1	5	16	65
Feng L.H., Huang C.F.	A risk assessment model of water shortage based on information diffusion technology and its application in analyzing carrying capacity of water resources	2008	Water Resources Management	22	5	621	633	57

Rank	Freq		Keyness	Effect	Keyword	Rank	Freq		Keyness	Effect	Keyword
1	**156**	**+**	**39,01**	**0.0098**	**society**	20	17	+	4.66	0.0011	modern
2	**150**	**+**	**35.34**	**0.0094**	**technology**	21	21	+	4.61	0.0013	american
3	**60**	**+**	**11.91**	**0.0038**	**technologies**	22	12	+	4,6	0.0008	intake
4	77	+	10.91	0.0049	control	23	12	+	4,6	0.0008	liquid
5	37	+	7.93	0.0023	efficiency	24	12	+	4,6	0.0008	metal
6	20	+	7.66	0.0013	vibration	25	12	+	4,6	0.0008	noise
7	18	+	6,9	0.0011	neighborhood	26	22	+	4.51	0.0014	recycling
8	18	+	6,9	0.0011	quantum	27	15	+	4.48	0.001	stages
9	18	+	6,23	0.0011	n	28	11	+	4,21	0.0007	dc
10	22	+	5.97	0.0014	engineers	29	11	+	4,21	0.0007	metabolic
11	134	+	5.83	0.0084	systems	30	11	+	4,21	0.0007	steel
12	32	+	5.79	0.002	fuel	31	11	+	4,19	0.0007	technologists
13	15	+	5.75	0.001	reliability	32	55	+	4,14	0.0035	information
14	18	+	5.61	0.0011	engine	33	17	+	4,12	0.0011	coupling
15	15	+	5,08	0.001	motion	34	28	+	4,1	0.0018	field
16	15	+	5,08	0.001	open	35	14	+	4,05	0.0009	speed
17	13	+	4.98	0.0008	frequency	36	30	+	3,95	0.0019	innovation
18	13	+	4.98	0.0008	metals	37	120	+	3.95	0.0075	which
19	16	+	4.85	0.001	cell	38	44	+	3.89	0.0028	urban

System Dynamics Review
Xitong Gongcheng Lilun yu Shijian/System Engineering Theory and Practice
SAE Technical Papers
Journal of Cleaner Production
Journal of the Operational Research Society
Binggong Xuebao/Acta Armamentarii
Physical Review A



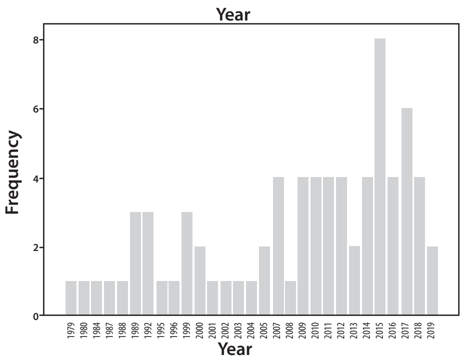
Studies •

Appendix 3. Top cited papers; word keyness in abstracts; frequent journals, yearly publications – System dynamics and Gaming

Authors	Title	Year	Source title	Volume	Issue	Page start		Cited by
Jahangirian M., Eldabi T., Naseer A., Stergioulas L.K., Young T.	Simulation in manufacturing and business: A review	2010	European Journal of Operational Research	203	1	1	13	302
Senge P.M., Sterman J.D.	Systems thinking and organizational learning: Acting locally and thinking globally in the organization of the future	1992	European Journal of Operational Research	59	1	137	150	193
Shaeffer D.K.	MEMS inertial sensors: A tutorial overview	2013	IEEE Communications Magazine	51	4	100	109	120
Sterman John D.	TESTING BEHAVIORAL SIMULATION MODELS BY DIRECT EXPERIMENT.	1987	Management Science	33	12	1572	1592	109
Morecroft J.D.W.	System dynamics and microworlds for policymakers	1988	European Journal of Operational Research	35	3	301	320	106
Bakken B., Gould J., Kim D.	Experimentation in learning organizations: A management flight simulator approach	1992	European Journal of Operational Research	59	1	167	182	54
Kristianto Y., Helo P., Jiao J., Sandhu M.	Adaptive fuzzy vendor managed inventory control for mitigating the Bullwhip effect in supply chains	2012	European Journal of Operational Research	216	2	346	355	53

Rank	Freq		Keyness	Effect	Keyword	Rank	Freq		Keyness	Effect	Keyword	Rank	Freq		Keyness	Effect	Keyword
1	**78**	**+**	**110.94**	**0.0121**	**gaming**	23	50	+	11.98	0.0077	management	100	18	+	5,27	0.0028	issues
2	**62**	**+**	**73.54**	**0.0096**	**game**	26	21	+	11,4	0.0033	complexity	101	21	+	5,27	0.0033	modelling
3	55	+	49,02	0.0085	learning	28	10	+	10.68	0.0016	publications	102	13	+	5,04	0.002	make
4	**31**	**+**	**43.39**	**0.0048**	**games**	29	11	+	10.58	0.0017	team	104	16	+	4.88	0.0025	international
5	25	+	30,9	0.0039	interactive	34	35	+	9.49	0.0054	supply	105	10	+	4.78	0.0016	experience
6	88	+	25,04	0.0134	simulation	35	24	+	9.46	0.0037	about	109	13	+	4.74	0.002	perspective
7	45	+	23.66	0.007	decision	36	29	+	9.32	0.0045	making	115	18	+	4.55	0.0028	decisions
8	22	+	21.88	0.0034	p	37	10	+	10,03	0.0016	agents	116	14	+	4,43	0.0022	need
9	31	+	19.59	0.0048	chain	38	13	+	10,03	0.002	media	117	10	+	4.43	0.0016	aspects
10	14	+	19,02	0.0022	online	40	34	+	8.71	0.0053	models	118	30	+	4.43	0.0047	performance
11	14	+	19,02	0.0022	players	42	33	+	8.62	0.0051	social	119	11	+	4.41	0.0017	demonstrate
12	23	+	17.54	0.0036	group	43	10	+	8.61	0.0016	agent	120	93	+	4.41	0.014	with
13	14	+	17,12	0.0022	bullwhip	50	16	+	8.42	0.0025	role	121	16	+	4.38	0.0025	human
14	15	+	16.82	0.0023	environments	51	17	+	7.95	0.0027	computer	145	21	+	4,23	0.0033	effect
15	17	+	16.55	0.0027	students	54	21	+	7.59	0.0033	they	151	20	+	4,12	0.0031	value
16	16	+	15.21	0.0025	participants	55	59	+	7.42	0.0091	based	152	11	+	4,1	0.0017	allows
17	14	+	14.65	0.0022	play	67	11	+	7,14	0.0017	virtual	153	11	+	4,1	0.0017	behaviour
18	30	+	14.36	0.0047	business	68	16	+	6.95	0.0025	tool	154	19	+	4,02	0.003	support
19	12	+	14.29	0.0019	reality	72	16	+	6.62	0.0025	article	174	13	+	3.91	0.002	tools
20	16	+	13.29	0.0025	managers	81	20	+	5.91	0.0031	real	175	13	+	3.91	0.002	where
21	13	+	13.29	0.002	user	82	28	+	5.78	0.0044	complex						
22	25	+	12.53	0.0039	world	92	59	+	5.38	0.009	systems						

Simulation and Gaming
European Journal of Operational Research
Journal of the Operational Research Society
System Dynamics Review
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)



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