Exercise 'Technology Assessment' through a gaming procedure

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Abstract: How to train advanced university students for 'Technology Assessment' (TA)? Which type of *social process design* is best for learning social and academic skills? A new negotiation game ('Surfing Global Change')[1] tries to give an answer. Its *graphic design* elements represent the underlying e-learning concept. Analysis highlights the *importance of rhythmisation* in the social processes in order to safeguard *training efficiency* for different initial levels of proficiency in a class. *Multi-perspectivism* is facilitated by taking *roles* of different stakeholders. We understand *'design'* in a universal way as a *compound of temporal, spatial and inter-individual structures facilitating the realisation of processes*.

Keywords: Technology Assessment; TA; engineering education; game-based learning; social design; consensus building.

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Biographical notes: Gilbert Ahamer graduated in Technical Physics, Technical Environmental Protection, Business Administration & Economics, and has taught interdisciplinary web-based courses for eight years at five Austrian universities. He learns from his students by watching the emerging socio-dynamic patterns during class and hopes that similar levels of activity may arise in the environmental administrative domain, to which he has been firmly committed for some years. The poor performance of national climate policies convinced him that autopoietic evolution of societal structures is needed as auxiliary force to combat global climate change. This paper tries to develop some first elements of such social processes.

Christian Schrei is a graduate in information design from the University of Applied Science Joanneum in Graz, Austria, and does graphic, web and human interaction design for a wide range of institutions and companies. Following the tone of his Master Thesis titled 'Minimal', his focus is set on simplifying complex matters, while retaining a certain level of sophistication hidden below the surface.

1 Introduction: question and context

1.1 Target of this paper: how to design social processes?

The background of this paper is to elaborate a helpful *method to train* advanced engineering students in '*Technology Assessment (TA)'*.

The main problem dealt with in this text is: How can educational processes be suitably designed in order to provide a series of social patterns and situations which are characteristic for real-life procedures encountered during 'Technology Assessment'?

Hence the issue at the core of this paper is the '*design of social processes*'.

The main question to be addressed and answered is: *Which type of social process design delivers* to engineering students *a suitable framework* of fact-oriented work, dialogue and consensus building?

The text in the rest of Section 1 introduces into the *mutual relationship of TA, Design and Gaming*. As a consequence of this interrelationship, a negotiation game is proposed.

1.2 Technology Assessment (TA) as the starting point

The relevance of TA in present-day *engineering education* is among others

- to incite the actors to take an interdisciplinary view (include ecology and social sciences)
- to respect the interlinked complexity of matters (systems analysis)
- to enter a dialogue between the actors (process orientation, ethics of negotiable contracts).

For *designers*, TA could be additionally understandable as a mental strategy to arrange in proper order the multitude of arguments in a complex real-world case. Designers could try to see TA as a methodology to organise the 'space of arguments' in harmonious manner.

Therefore, let us now take a closer look on what TA is:

'Technology Assessment' is a *dialogue-oriented approach to issues*, problems and critical questions in technology and engineering. For decades since the 1960s, TA (Hetman, 1973; Illich, 1975; Böhret and Franz, 1982; Nowotny, 1985; BMFT, 1987; Neisser and Brünner, 1993; Ahamer, 1999; UVP-report, 2005) has attempted to

- analyse technological developments in an anticipatory manner
- assess their consequences for society and environment
- compare probable effects with relevant ethical concepts and
- deliver resulting recommendations to the political and economic spheres.

TA is fundamentally *interdisciplinary* (Grunwald and Schmidt, 2005; Ropohl, 2005), described in often dispersed literature but is consistently integrated and defined in a recent book (Grunwald, 2002).

Albeit TA was born out of a tradition of '*civic responsibility*' during the late 1960s, present legislation does not know a peculiar law regulating TA – neither in Austria, nor elsewhere in the world, as far as we know (Covello et al., 1985; Hochgerner, 1990). The closest relative to such political culture is the obligation for '*Environmental Impact Assessment*' (EIA), implemented among others within the EU (EIA, 1997; UBA, 2005a) and US legislations. Such a project-oriented approach is currently complemented by 'Strategic Environmental Assessment' (SEA, 2001; Thérivel, 2004; Aschemann, 2004) focussing on policies and programs.

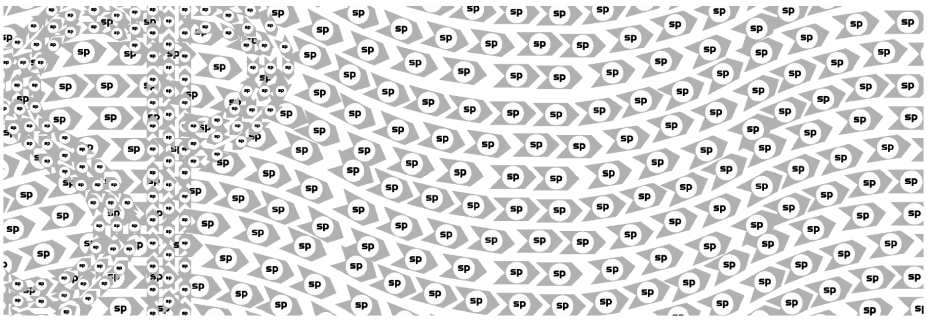
Since its historic emergence, TA has always had a strong inclination towards *participation* (Feichtinger and Pregernig, 2005; Burger, 2005; Purker, 2005) of citizens and has adhered to constructivist dialogic 'weltanschauung' in the tradition of 'ethics of negotiation'. TA was much more viewed as a *procedure* as opposed to a final state presenting the 'true balance' of economic vs. ecologic interests.

1.3 Both Technology Assessment (TA) and gaming focus on social processes

The following text aims at devising suitable ways of *designing social processes*.

A definition: '*Social processes*' (sp, small arrows in Figure 1) are defined for usage in this paper as general *elements* of more complex long-term societal procedures (SP, which are here defined as compounds of the elements sp, optically represented by a texture in the structure of Figure 1). The single processes sp could be: group formation, fact based discussions, review processes, structured debates, consensus finding, balancing of actors' interests, and implementation of consensus solutions. Social processes are the small elementary particles (lasting hours to days) of societal procedures SP (e.g., a TA lasting weeks to years), which in turn are embedded in the entire stream of societal evolution (lasting decades or still longer if understood as 'history of civilisations' (Duby and Mandrou, 1958)).

Figure 1 Symbolic representation of structures: single 'social processes' (arrows 'sp') may aggregate to more complex 'Societal Procedures' (letters 'SP')



TA apparently consists of such *elements* sp (e.g., interdisciplinary analysis, balancing of arguments, consensus finding and implementation), according to textbooks and more concise "cooking recipes for good TA" (Rakos et al., 1988, 1997; Böhret and Franz, 1982; Smits et al., 1987; Stähli, 1998; Grunwald, 2002). Hence it seems to be useful to train such elements (sp = social processes) in order to prepare students for best performance in professional life. At the same time, *gaming* seems to consist of the same or similar elements, especially role-playing in real-life simulations.

Compact analyses of games' applicability in 'a world of infrastructure' were conducted in Mayer and Veeneman (2002). Double manifold structures were introduced into gaming in the shape of fact-based interdisciplinary and viewpoint-based (Mayer and Veeneman, 2002, p.10) *multi-perspectiveness*, which can be reified through teams with predefined roles that have previously been individually specified within the scope of the player's interests (Ahamer, 2005a).

The core idea of 'taking roles' is to facilitate 'understanding (others') perspectives'. In classical technological training at universities and elsewhere, the problem of content-centred approaches is that they often fail to leave sufficient space for adopting action-oriented discursive skills and changes of perspectives, which is however one of the necessities for TA (Jobst et al., 1992; Melezinek, 1992).

The above Section 1.3 showed that gaming and TA walk on similar tracks, because both focus on social processes (and not purely on fact-based knowledge). By this similarity, gaming – more specifically role-playing – could lend itself as an option for an educational method to train TA.

1.4 Design of consensus building

Design of consensus building is the larger perspective of 'education for TA'. TA is an instrument for identifying possible societal consensus (Tschiedel, 1989; Walther, 1992; Zweck, 1993) with a view to implementing it. Both TA and role-playing take as 'elementary particles' of their world view the relations between actors but not 'eternal truths' (Huber, 1989; Inhoffen, 1993).

According to the guidelines of this special issue, studying the necessities in building consensus calls for

- procedures with the participation of *multiple stakeholders* that are intertwined
- an *iterative structure* of process design which allows for building on interim results developed prior to the current state.

Games (relevant subgroups are named simulation games or negotiation games, cf. Mayer et al., 2004a, p.31, 2004b, p.180, 2004c, p.324ff)) are often selected as a method for training 'consensus building' because they focus on

- the *action* of solving instead of the status of solution (i.e., having in mind the next useful step that takes account of the stakeholders' concerns at that moment, cf. Veeneman, 2002, p.186f)
- understanding learning as *interaction*, not only as *acquisition*; focusing on procedural, not declarative knowledge (Klabbers, 2000, p.396f)
- the individual *perspectives* instead of the depersonalised truths (cf. the multi-layered administrative process of EU enlargement (Ahamer, 2005c) and the tedious scientific and political process of national (ACCC, 1998) or global (IPCC, 2001) climate negotiations)
- the *situatedness* of a case study instead of academic objectivity (Sense, 2004, p.131), 'inculturation into reality' (Vrasidas and Zembylas, 2004, p.328)
- *collective* argumentation depassing individuals' skills (Schwarz et al., 2003)

- *negotiable views* instead of traditional 'true-false' logic (analogous to negotiations during Environmental Impact Assessment (UBA, 2005b))
- providing a *loose* enough *corset of rules* in which players are allowed to behave according to their intrinsic motivation and develop inventive strategies
- *playing* a role, which allows to 'lean out' of one's own convictions without leaving them ultimately
- the 'artificial' setting in an atmosphere where *consequences of decisions* become visible but not painful (error-free – consequence-free – pain-free)
- slipping into a role, which allows – but not forces – to place one's own system of factual understanding into another 'nodal point' within the tissue of interests and network of tensions.

1.5 A gaming procedure trains Technology Assessment (TA) skills

As mentioned above, the main *question* in this paper is: what type of social process design is suitable for *TA training* purposes? A game? Any *answer* to this question should care for

- a complex multi-protagonist environment (i.e., negotiation game)
- facilitating multi-perspectivism (reified by role-playing teams)
- an iterative, hence error-friendly solution path (i.e., multi-level game)
- highlighting optimisation of dense peer communication (mutual assessment)
- working independently of time and space (i.e., web based implementation)
- autopoietic motivation (i.e., orientate to peers' skills, not to lecturer's skills)
- wide applicability to any theme in engineering or design education (restriction to merely procedural game rules, no rules contingent on content).

1.6 The case of 'Surfing Global Change' (SGC)

'*Surfing Global Change*' (SGC) is presented here as a case for an answer to the above question because its design combines several forementioned elements (social processes like review, debate, consensus finding) and trains for them in iterative levels. SGC is used as case both for illustrating educational ideas and for determining effectiveness of that educational strategy.

The term 'Global Change' is understood as long-term development of the global human living conditions; its publicly most known part is environmental global change, of which climate change is a very relevant example. The word 'Surfing' in the title pertains to making use of long-term trends and to ride (or surf) on them whilst trying to achieve targets of a sustainable future – this means where economic and ecologic needs of mankind are pursued in an equilibrated way.

The complete set of its *rules* is published in Ahamer (2004b, 2006), and its web-based implementation in Ahamer (2005a). Within e-learning, SGC represents the third out of three generations conceptualised in Ahamer (2005b). SGC or a similar approach can also be used in the context of administrative, institutional or industrial consultancy (Fabrik der Zukunft, 2005; Fresner, 1998).

1.6.1 Basic characteristics of Surfing Global Change (SGC)

The *learning objective* of the five-level game SGC is to master the processes needed for consensus building as is prevalent in and demanded by many developed societies. This game will be explained in Sections 1.6 and 3.

The main *characteristics* of SGC are: it is

- a suite (= 'composed series') of role play
- both web-based and requiring physical presence
- an open learning environment
- well compatible with team teaching
- a 'dramatic shell' for training soft skills, highly adaptable to themes
- suitable for 8 to some 40 players
- convenient to last several weeks up to two semesters.

The *five game levels* ask the players in SGC to:

1 learn content as an academic basis and pass quizzes

2 draw up and review personal standpoints concerning a frame theme

3 win in a competitive discussion regarding a concrete case study

4 create a consensus for the same case study

5 place the case study into the context of global long-term trends.

SGC represents no 'new learning platform' or other tangible software. It consists in a *set of rules* and is (as chess) independent of the physical material needed for it. It lives from its ideas and its pedagogic foundation (Ahamer, 2004a).

SGC can be played with almost any (sufficiently complex) *theme*. What themes have been addressed during the eight SGC implementations so far?

- TA (cases e.g., tunnel crossing the Alps, power plant)
- Global Change (water supply and economics)
- Climate Change (fossil CO_2 emissions, low-energy houses)
- EU enlargement and environment (air quality in Slovakia)
- Environmental technology (e.g., impact of mobile phones).

1.6.2 Increasing complexity along the levels of Surfing Global Change (SGC)

Along five consecutive levels (compare Figure 4 and Section 3.1), the players face the following overall tendencies:

- learn and apply *facts* in increasing complexity
- interact with each other in *relationships* of increasing complexity
- document their intermediate results (on a learning platform) while taking increasingly combined *perspectives*.

The following sections provide to the reader as follows:

- Section 2 focuses on concepts for social process design, like rhythmisation
- Section 3 goes into details of (graphical) game design and (social) processes
- Section 4 speaks of evaluations and experiences with case studies
- Section 5 analyses the resulting social skills and social dynamics
- finally conclusions are drawn while reflecting on gaming and training for TA.

2 Concepts for social process design

When looking from a distance, there could be *two fundamentally different modes of understanding* the relationship between '*gaming*' and '*design*':

- Gaming (i.e., playing simulation games) is one of many possible designs of social processes (i.e., how social interaction is directed): this was discussed above in Section 1, will be elaborated further in this Section 2 and applied to the case of SGC in Section 3.
- The relevance of gaming (as an educational method) for design (i.e., design education) is not central to this paper (although gaming does represent an educationally wise strategy). Only, Section 4 describes practical teaching experience from technological curricula (i.e., not exactly design curricula).

2.1 What is the meaning of social process design?

The understanding and promotion of *social dynamics* (Rauch, 1985, 1999) is key to 'Surfing Global Change'. SGC wants to use web-based media for enhanced social innovation. The main interest of SGC is not so much a technologically highly sophisticated e-learning product, but the innovative design of the involved social processes.

For participants, SGC amounts to a gradual constructive task: to classically learn some basics, merge them into a standpoint, then to win a dispute of arguments and finally reach a consensus-oriented solution encompassing multiple perspectives.

For this purpose, form (here: types of processes) is to be matched with content (here: TA). For Lloyd (2004) "a designer (…) is someone skilled in matching form to content".

The *stepwise mental construction* task in SGC is planned to be equivalent to a 'stepwise procedure' of education. Each step builds on the previous one in the sense that cognitive (and communicative) skills need earlier achievements as basis and substrate (Table 1).

Table 1 Steps in the procedure of education are equivalent to steps (levels) in SGC

Education takes place in steps	*Analogous steps* (*levels*) *in SGC*	*No.*
Perceive facts and adopt them for own reasoning	Learn single facts and small parcels of knowledge	1
Perceive what others think and evaluate the difference to one's own opinion	Take enough time to read what colleagues think and apply critical review	2
Apply own reasoning, and defend it by arguments	Communicate own viewpoint and find counter-arguments in a discussion	3
Integrate own understanding into the views of others	Contribute to the generation of consensus among different stakeholders	4
Draw up a consistent picture of a complex theme	Draw up 'all' possible viewpoints by own initiative and equilibrate them	5

Consequently it appears as crucial that *suitable sequences of situations* are presented to the learner: this is what 'social process design means'. Border conditions for learning (e.g., acting alone or in group, atmosphere of competition or of collaboration) should change in a way that the learning effect is optimised.

2.2 Design grammars: patterns of rhythmisation

In this journal, Beilharz (2004) authored a very interesting interdisciplinary study combining music and architecture (we understand them here as special disciplines for 'designing', see directly at http://jdr.tudelft.nl/articles/issue2004.02/Art2.html#6). She identifies "procedures and structures that traverse both (in her case: music and architecture) disciplines" and emphasises the importance of "design grammars and generative systems" (in her case devised by the architects Xenakis and Le Corbusier) as common principles of structurisation.

In her example, Xenakis' sequential programming of both the façade of the Couvent de Sainte Marie de la Tourette (cf. his 'Modulor system') and in his serial music ('stochastic grammars') exhibit very inspiringly the importance of rhythmisation.

An *analogous idea of rhythmisation* is proposed here *for social procedures in education*. This means that each student is enabled to encounter alternating communicative situations of different kind (being author vs. reviewer, actor vs. spectator, part of a controversy vs. part of a consensus) in which they take different roles or 'wear different hats'.

Rhythmisation means here that

- an outer temporal stress (e.g., deadlines) co-determines players' activities
- roles of players oscillate from active to passive (e.g., writing, reviewing)
- atmosphere switches from competitive to collaborative and back
- players are forced to take different, even contradictory perspectives
- results of preceding processes are starting points for subsequent processes
- degrees of differentiation in reasoning and argumentation vary (see Section 2.3)
- needs to improve results can be easily met in a subsequent step and shortcomings can be outperformed in a later step.

Summing up, this Section 2.2 has pointed out that appropriate *rhythmisation* (along space, time, but also regarding opinions, perspectives and human interaction) can be used as supportive feature in successful design, be it of social, musical or architectural type. Section 4.2 will illustrate that the concept of rhythmisation can pertain to time, communication patterns, perspectives of argumentation and roles.

Section 2.3 takes the example of 'degree of differentiation' as one case for a *single step* in rhythmisation.

2.3 Degree of differentiation into details and structures

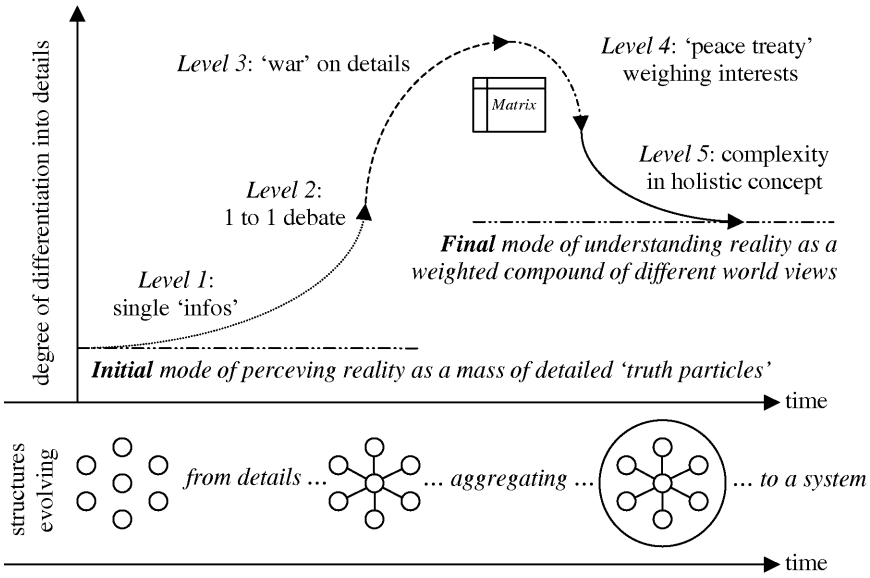
Along any procedure of understanding complex socio-technological matters (which is a characteristic of TA), the level of detail of consideration varies. Naturally, in an initial state, limited understanding implies low levels of scientific differentiation, which are likely to rise during the reoccurring incidents of scientific investigation, alternating with interpersonal exchange of viewpoints, e.g., in a participatory TA procedure. By nature, consensus finding reduces the multiplicity of contemplated facets and boils them down to practically feasible project proposals, which in themselves contain the results of weighing processes and the balancing effort regarding relevant values. Such a dramatic sequence may resemble a TA procedure (Rakos et al., 1988; Kolar, 1988), an EIA procedure (UBA, 2005b) or possibly also a designing procedure recasting an (only preliminarily or deliberately) ill-defined task into an identified functional structure after dialogic search processes (Perry and Sanderson, 1998; Maher and Tang, 2003; Maher, 2000; Dorst and Cross, 2001).

Figure 2 sketches the descriptive parameter "degree of differentiation into details". The *essential issue* is that *a 'structure' is created* – codified by the matrix icon or by the snow star icon. By running through the path of time, a structure has emerged and matured. This mental structure might prove to be 'indelibly learned' by the actors, since it was created as own brainchild and not imprinted from outside.

What was described in general terms above is equivalent to the SGC dramaturgy in a nutshell. The *act of learning* is considered as optimal when occurring as by-product of a personal strategy "how can I convince others?" but not when answering to an outside appeal 'learn that content!'.

The '*genesis of structures*' is at the very centre of these (autopoietic, i.e., self-organised, see Ossimitz, 2000) *learning paths*. Such fine super-structures realigning already known facts are almost tacitly 'learned' (= created by the learners themselves while they consciously strive for another target, e.g., convincing others), appear as the most precious learning result and could easily be overlooked by the bystanders, especially if they act as traditional 'teachers'. As an analogy, in a cold winter a snow star silently appears overnight after water molecules have coalesced, coagulated, rearranged and crystallised out slowly whilst facing only low external physical impact to do so. In this picture, the matrix serves as 'nucleus of cristallisation' for learners' views.

Figure 2 Depiction of one parameter characterising the process of understanding in any educational system: "degree of differentiation into details". As SGC proceeds (to the right), differentiation rises and then drops to a level lower than the maximum after having co-created a structure facilitating understanding. See Section 4.2 to explain the 'matrix'



If ever the promising concept of "oscillation between problem space and solution space" (Maher, 2000; Dorst and Cross, 2001, p.434) develops carrying capacity, this concept should be discernible here as well: yes, each 'intermediate result' along the procedure becomes the 'initial state' in the subsequent procedural step. For example, the preliminary analysis in the style of a small value benefit analysis leads to the matrix (symbolised in Figure 2 above centre), which in turn becomes the "(battle)field on the game table" for the Level 3 discussion. In anonymous surveys, students' feedback occurred as follows: "if I had known the effects of making the matrix, I would have worked on it more carefully" – a first attempt to switch back to the other space.

2.4 Organic developments along all five levels of Surfing Global Change (SGC)

The overall design of the game SGC tries to implement a certain rhythm of fact-based analysis in alternation with social striving for acceptance of such personal convictions:

- phases with focus on individual work (1, 2, 5) complement with team oriented phases (3, 4)
- phases with focus on defending individual views (1, 3) alternating with phases where openness for other standpoints is a necessary attitude (2, 4)
- phase 3 with its richness in differentiation and details as visualised by the matrix is followed by phase 4, where formerly single aspects are intertwined and where details converge to a common action program.

The main dramaturgy of SGC lies in "arguments serving as *tools* for objectified interpersonal communication":

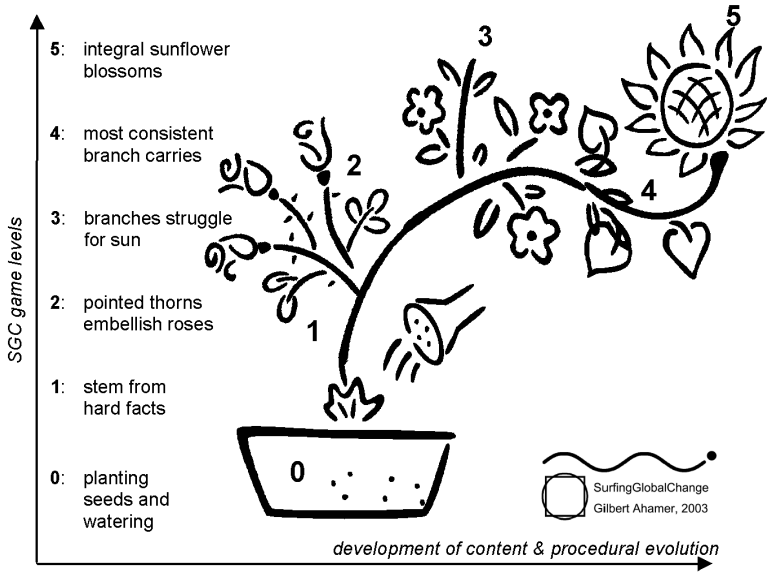
- *first* define and foster your own precise standpoint in order to
- *then* become able to flexibilise it for the sake of the greater equilibrium.

SGC gamers 'dance' through the 'space of arguments', employing but re-interpreting and re-arranging traditional dancing steps and figures.

Such flexibilisation increases the degree of freedom that ultimately allows for game-play. According to design literature (Cross, 2004, p.429), "designers act, as if a problem was ill-defined, even if it is well-defined", in order to enrich the potential solutions.

In this light, SGC's set of rules could be seen a facilitator for non-directive (SiP, 2005) social and academic evolution within a course that has several organic functionalities (Figure 3).

Figure 3 Symbolic depiction of the consecutive social processes, in which the five levels of 'Surfing Global Change' (listed in Table 1 and Figure 4) unfold: the evolution from dwelling upon single technical details (Level 1) towards a coherent interdisciplinary view (Level 5) is similar to the growth of a plant being watered by arguments in search of the light of consensus



2.5 Modes of experience addressed

In order to structure the experiences during the eight implementations of SGC to date, the outlay of Dreyfus (2003) as cited in Dorst (2004) is used in Table 2 as vertical axis. The rightmost column lists behaviour encountered with SGC participants.

Facing such a concept of seven modes as consecutive epochs in apprenticeship, it should be added that each individual exhibits different modes in different respects. For examples, students might be experts in coalition building, but novices in traffic technologies or infrastructure planning. Hence, a "rolling (= successive) evolution of competence building" might be appropriate – where patterns successfully learnt for one skill might positively affect the speed of learning in other skills.

Anyhow, SGC must yield a stage for all profiles and for players living in any mode; hence, the educational degrees of freedom must be sufficiently large. Another consequence is that SGC resembles more a suite of games with different gaming constellations than one single game. Section 5.1 will refer to Table 2 again.

Table 2 Reflection of one's own experiences with role playing using the seven distinct modes of expertise according to Dreyfus (2003) in the Amsterdam lecture

	Mode of expertise	*Explanation by Dreyfus (2003)*	*Example: behaviour found in SGC participants*
I	Novice	Consider the objective features, follow strict rules	The 'followers of the rules' in technologically oriented curricula
II	Advanced beginner	Situational aspects are important, exceptions from 'hard' rules	Selected innovative students in technological curricula at FH
III	Competent problem solver	Selects the relevant elements, chooses a plan to achieve goals, seeking opportunities, emotional attachment, trial-and-error	Students from interdisciplinary curricula (Uni), experienced in retrieving information they need; "professionals like more to learn"
IV	Proficient problem solver	Immediately sees the most important issues and the appropriate plan, reasons out what to do	Very advanced interdisciplinary students and junior lecturers following a 2002 summer course
V	Real expert	Reponds intuitively, performs appropriate action straightaway. No problem solving and reasoning	Senior lecturers and all participants in summer seminar 2005 on education
VI	Master	Sees standard ways as contingent, deep involvement in field as a whole, dwells on success and failures, nuanced appropriateness	All SGC participants were asked to adopt this role after the end of gaming: to critically view the method, no more the issue
VII	World discloser	Visionary, strives to extend the domain, develops new ways, opens new worlds, operates on the margins of a domain	Readers of this paper: reflect motives and visions play with rules ➔ new rules will be developed ➔ new mode (I)

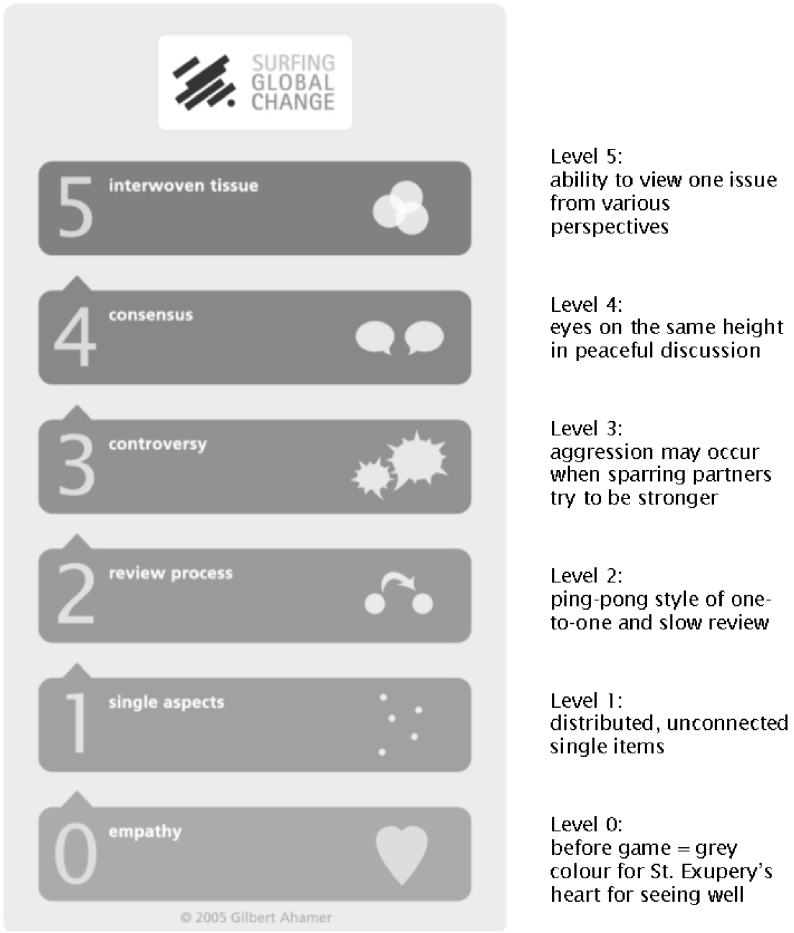
3 Game design and processes

3.1 Explanation and implementation of Surfing Global Change (SGC) game rules

The complete set of SGC game rules has been published in Ahamer (2004b, 2006) and is also available to registered online players. Due to reduced space, in the present publication the detailed description is omitted. Detailed rules of Level 2 can be found in Ahamer (2005c) together with an analysis of the review situations. Detailed rules of Level 3 can be found in Ahamer (2005a).

'Surfing Global Change' sets out to permit organic maturation of standpoints across five levels (compare Figure 4).

Figure 4 Symbolic depiction of the social and communicative setting, in which the five phases of SGC unfold: the evolution from dwelling upon single technical details towards a coherent or even holistic view



On the web, this sequence of five levels is implemented as follows:

1 *Small isolated packages* of traditional content rooted in single disciplines, representing only 'one side of the medal'. In the web-based implementation, students read and study lecture notes and pass a web-based quiz. They fill in a web-based initial (and final) survey.

2 *Process of text-oriented criticism* at slow pace permitting deliberation on a one-to-one basis mediated via asynchronous virtual communication. In the web-based implementation, students post a standpoint of 1 page in the discussion forum, review the colleagues' standpoints via the 'reply' function, assess using $n = 1$ to 5 points and eventually collect points as reviewer (namely 5 minus n, hence as a function of severity in their assessment).

3 *Quick processes* with a *need to present and defend one's own arguments* in a controversial debate as a function of the adversary's behaviour and strategy; on a many-to-many basis inside a team in synchronous real-time communication. In the web-based implementation, two weeks before the discussions all teams prepare a matrix differentiating the complex theme into grid cells (in the spirit of TA, see Section 1.2 or of value benefit analysis, see Section 4.2), post standpoints one week before the discussion, on the day of discussion set chips onto single grid cells (equivalent to the 'weighing processes' in value benefit analysis) and engage in vivid face-to-face discussions for each grid cell. Their success is monitored and decided upon by colleagues. Received points are depending on their voting decisions. The same procedure is repeated with exchanged functions: discussants become voters, voters become discussants (see complete Level 3 rules in Ahamer (2005a)).

4 *Consolidation process* with less pressing time restrictions in real-time communications on a many-in-one-boat basis in the need of consensus in synchronous real-time. In the web-based implementation, one week after the debate the same teams write up one single paper, which takes into account all requirements of all stakeholder teams; they win points depending on the degree of quality of their consensus.

5 Closing activity of *creating a view that integrates* all voiced standpoints by creating an analysis (outside severe time restrictions) as an individual or in a freely chosen team, on a we-just-for-us basis, in a web-mediated asynchronous communication context. In the web-based implementation, students post individual written assignments integrating a holistic view.

3.2 How literature has inspired the five levels

The five levels are rooted in educational and philosophical concepts that can be found – independently of SGC – also in earlier literature:

- *Level 0.* Delivery of content in the classical sense is focused on procedural knowledge, which is held to constitute 'relevant learning' (Rogers, 1974), for example the ten major steps in 'Technology Assessment' procedures (Rakos et al., 1988) or the characteristic forms of 'Systems Thinking' (Ossimitz, 2000). Students were steered towards a pedagogical path, where they were able to

'rediscover' basic physical, chemical or technical insights during the course together with the trainer (Montessori, 1988).

- *Level 1*. A modified '8-4-2 words' game from Thiagarajan (2001) was used, which is similar to the Delphi method (see the list of creativity techniques in Kolar (1988)). All students have to define key concepts by 8 words and vote anonymously for the best explanation, then the same is done by 4 and 2 words. The objective is to differentiate the basic aspects of the intended project theme, but also to digest underlying fact-oriented and technical knowledge (Barrows, 2002).
- *Level 2*. (a) Review processes are key to the generation of *scientific* literature: comparing the ISI Thomson Science Citation Index SCI or Social Science Citation Index SSCI (ISI, 2005). (b) In *complexity science*, answered action, called 'double interaction' (Weick, 1979 as cited in Klabbers (2003, p.577)) leads to community structures that show dynamic stability (c) In the *diplomatic* tradition, an exchange of reports and perspectives is the essential procedural element (Ahamer, 2005c). The same applies to any intercultural (Global Studies, 2005) activity. We could even say: 'truth' is only what is accepted by our partner during negotiations, everything else is irrelevant. Isn't that a constructivist approach? In SGC also assessment is done through a review process (Sivan, 2000).
- *Level 3*. (a) On the *dramatic* level, a competitive atmosphere can be observed that leads to an argumentative battle between conflicting standpoints (compare Naidu et al., 2003; Reilly, 2003). (b) On the *content* level, we attempt a maximum degree of differentiation into single aspects (viewpoints placed physically to four desks). (c) Regarding the *genesis of structure*s (cf. Section 2.2): In an interesting paper on "Gaming and simulation: Principles of a science of design", Klabbers (2003, p.579) cites Giddens (1993, p.128): "Social structure is both constituted by human agency and is at the same time the medium of this constitution" and concludes personally: "Because of the duality of structure, [participants] can also *switch position*, from *inside* participant (actor) to *outside* observer. In such case, they can question their motives and personal efforts, the rules, and/or the resources to develop strategies for the maintenance or transformation of the social system". This quote expresses exactly what Level 3 heads for: switching social functions!
- *Level 4*. de Chardin's (1969) global and evolutionary view (which is why he was 'expelled' to China by his Jesuit superiors in the 1950s) proposes a period of differentiation (such as the tremendous ramification of the biological species), and subsequently a period of convergence (in his case towards 'point omega') which in our times could be mediated by the appearance of the world wide web. In SGC, differentiation into species is replaced by differentiation into details (Figure 2), but the idea of "differentiation followed by integrating convergence" persists.
- *Level 5*. We interpret complex reality by global long-term mega trends, which are taken from the author's 'Global Change Data Base' (GCBD, Ahamer, 2001). Such a viewpoint resembles 'evolutionary economics', a new academic branch, whose name has already been adopted as title for a scientific journal as well.

3.3 Implementations of Surfing Global Change (SGC) to date

Until 2005, the following implementations have been performed, amounting to a total of 25 Semester Periods per Week (SPW):

- Compulsory lectures 'Technology Assessment' and 'Systems Theory and Biology' in the curriculum of 'Management of Civil Engineering' (BBM) with 2 SPW each at the University of Applied Science FH Joanneum (FHJ) Graz annually from summer semester 2003 onwards.
- Compulsory lectures 'Environmental Technology' and 'Systems Theory and Biology' in the curriculum of 'Industrial Electronics' (IEL) with 2 SPW each at the University of Applied Science FH Joanneum Kapfenberg annually from summer semester 2003 onwards.
- Compulsory interdisciplinary practical training 'Interdisziplinäres Praktikum' in the curriculum of 'Environmental Systems Analysis' (USW) with 6 SPW at Karl-Franzens University Graz on the theme "Global Change in our interdependent environment" taking the example of global water management during the winter semester 2003–2004 (Ahamer et al., 2003b) and on the theme 'EU enlargement' in winter semester 2004–2005 (Ahamer et al., 2004).
- The concept of SGC Level 3 is at the same time the game idea and game concept (Ahamer, 2003) as well as game scenario (Ahamer et al., 2003a) for the web-based implementation of "Social Skills and Knowledge Training".

3.4 Graphic design for Surfing Global Change (SGC)

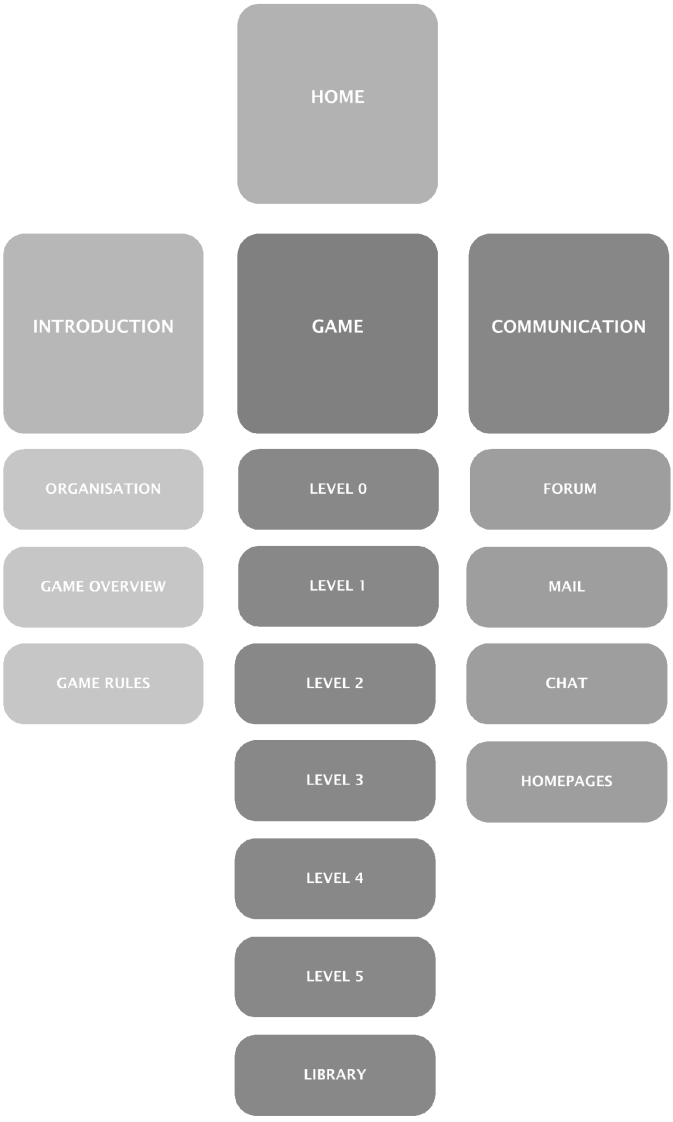
It was attempted to mirror basic characteristics on the web by suitable graphic design. The contribution of the second author consists in having developed in 2005 the new online graphic design for 'Surfing Global Change' and having considerably improved the usability of the web platform. Beforehand in 2004, an anonymous expert assessment of web-based SGC in the framework of a society on media didactics has had identified a number of deficits and shortcomings. On this basis, an improved logo (white rectangle above in Figure 4) and an improved screen flow were defined (Figure 5). As a result, the analogous expert review in 2005 yielded a better score.

3.4.1 The logo for Surfing Global Change (SGC)

The SGC logo (= icon on top of Figure 4) sets out to clearly represent the idea of 'Surfing Global Change' by graphic means:

- player steps up five levels after a point of departure
- five levels are only loosely connected to each other
- length of the bars is proportionate to the duration and intensity of the tasks to be performed by the players within each level
- gap between the bars is proportionate to the linkage of social processes between the respective levels
- five bars could eventually resemble a spinning globe.

Figure 5 The screen flow of SGC: three colours using the three main functionalities of the web platform WebCT (left column: yellow, centre: blue, right column: red)



The logo should

- be very typical and easily remembered
- be simple or even reductionist (Schrei, 2005)
- be easily geometrically scalable and usable both as icons (gif) or for documents (vector)
- express dynamism and unconventional orientation
- focus on the process orientation of SGC, not on a specific content.

3.4.2 Screen flow and icons

Following the three main functionalities of a web platform (Ahamer, 2005b), a defined scheme of three colours continues throughout the three main sections of SGC (Figures 5 and 6):

- *Yellow*: symbolises the introduction (item 'Introduction' is a key)
- *Blue*: symbolises the game (item 'Game' is the SGC logo)
- *Red*: symbolises communication (item 'Communication' is two faces).

The three logos on the top level of hierarchy are circled in (first row in Figure 5).

The game logo itself is consecutively filled with white as the game progresses (second column in Figure 5).

Regarding *Human-Computer Interaction*, a combination of real-life metaphors and abstract icons makes it as simple as possible (Schrei, 2005) to navigate the game interface with ease. A calendar icon can instantly be recognised as a reference to the game's time schedule, just as folder icons lead to a structured collection of data and lecture notes. These representations usually appear as unconsciously familiar, since they are also used in most operating systems, and therefore create a well-known environment. If there is no reference to real-life obtainable, a basic visualisation will guide the user.

Figure 6 The logos inside the game obey the three main functionalities (leftmost column: yellow, three central columns: blue, rightmost column: red)

To strengthen the game identity, the SGC logo is embedded in the gaming environment as a graphical indicator for the current level (0–5) in order to create recognition of the game's brand, while providing visual aid to better distinguish the different levels at the same time. Also, all icons used in the web platform follow the simple, yet effective colour scheme described above, which consists of the three main colours seen in the SGC logo.

An always visible, hierarchical navigation menu gives a sitemap-like overview of the whole game's content, thus providing very quick access, which is crucial for a frequently used gaming platform. The most excellent usability can only be achieved when the interface is not perceived as an actual interface anymore, but is used without having to think about it particularly. This graphic design philosophy relies on the theory of fading away the obtrusive interface to further optimise Human-Computer Interaction.

4 Evaluations and experiences with cases

4.1 List of requested feedback and evaluations of Surfing Global Change (SGC)

In this Section 4.1, the approach to quality assurance for the "architecture of the SGC procedure" is presented. Evaluation is at the core of SGC and has therefore also been repeatedly requested for SGC itself at multiple instances:

- Three independent reviews were commanded from experts on *education* and *social dynamics* in summer semester 2003 (see Section 5.2), amongst others by the editors of a book on self-organised education (Gierlinger-Czerny and Peuerböck, 2002). As a result, game rules were refined.
- Advanced students of *information design* have performed a critical analysis of the transferability onto a web platform in 2003.
- A *master thesis* was written in 2003 on the first implementation to seize the perspective of the students (see Section 5.1).
- *Regular* official benchmarking organised by the Graz University for all lectures has rated SGC close to the best score.
- Anonymous web based *initial and final surveys* have been performed in order to receive authentic students' feedback, they have yielded a very high degree of satisfaction of interdisciplinary students at Graz University but low satisfaction in more practical-minded curricula at the University of Applied Science FH Joanneum (because technological students might have perceived no easy link to their own professional practice).
- Four anonymous *expert reviewers* in the framework of a professional society for 'Media in Science' (Germany) have assessed SGC in 2004 and 2005.

As a consequence, SGC has been repeatedly refined in recent years.

4.2 Experiences with matrices from technologists' cases

The 'spirit of TA' was explained in Section 1.2, the SGC game rules were explained in Section 3.1.

A common methodology used not only in TA is *value benefit analysis*, in which an overall project is differentiated into single components. For example, a new by-pass road (to be planned in several variants) has economic, ecologic land-use related and other implications, which are to be differented to sub-levels in a tree-like structure. This method puts relative weights (according to the ascribed importance) on each sub-criterion, attributes scores (= fulfilment of sub-targets) and finally computes the sum of the weighted scores. The planning variant with the highest total score wins over the other variants. In SGC, such principal decision design is applied similarly: in Level 3 the role teams draw up a so-called 'matrix', which contains criteria and sub-criteria relevant to the assessed project, but only in the shape of a matrix and not in the shape of a list.

For establishing the matrix in stepwise teamwork, students first have to *identify key dimensions* of the theme (= row and column headings of the matrix) and then have to define suitable sub-themes (resulting from row and columns crossing) in the single grid cells of the matrix. Such a matrix acts as 'thematic landscape' for the discussion (comparable to the 'landscapes' in common civilisation games). Similar to a roulette desk, the grid elements are used for setting chips onto sub-themes.

In this section, the processes of Level 3 are documented for students of Industrial Electronics (see item 2 in the list of implementations in Section 3.3). They have selected the themes 'Climate Change' and 'Alternative Energy' and constructed the matrices in Figures 7 and 8 by *stepwise* consensus finding (i.e., individual matrix – matrix of a team – matrix of all involved teams). The role names of the teams are indicated under the matrices, also their abbreviations.

Figure 7 Matrix for the theme 'Climate Change' used for Level 3 with students of Electronics (IEL) in May 2003

CLIMATE CHANGE	Environment	Humans	Economy
Traffic	*15 min., FEL, G, EU, OG* Effects of increased traffic volume on global temperature rise	*0 min., no team* Comfort by mobility	*22 min., FEL, EU, OG* Transit
Laws	*20 min., G, EU* Eco-tax	*0 min., no team* Restriction or enhancement of quality of life by environmental legislation	*23 min., G, OG* Environmental obligations
Energy transformation	*0 min., only FEL* Emissions of power plants	*0 min., only EU* Use of energy	*0 min., no team* Efficiency of energy transformation

Fossil Energy Lobby	FEL
Greenpeace	G
EU Commission	EU
Opponents of Globalization	OG

Underlined = winning team

Figure 8 Matrix for the theme 'Alternative Energy' used for Level 3 with students of Electronics (IEL) in May 2003

ALTERNAT. ENERGY	Energy price	Environment	Quality of life
Subsidies	*11 min., G, AL, RP, C* Distortion of competition	*10 min., G, AL* Weighing of distribution of subsidies	*0 min., only G* Promotion of quality of life
Legislation	*0 min., only RP* Regulation	*0 min., only C* Targets	*10 min., G, AL, RP* Guaranteeing sustainability
Feasibility	*0 min., only AL* Rentability	*0 min., only C* Environmental Impact Assessment (EIA)	*13 min., AL, C* Consensus with neighbours

Government	G
Alternative Energy Lobby	AL
Regional Energy Provider	RP
Consumer of Energy	C

Underlined = winning team

The students used as dimensions of the '*Climate Change*' matrix (Figure 7) the affected areas of life (column headings: environment, humans, economy) and an approximation of emitting sectors (row headings: traffic, law, energy transformation); hence created approximately a two-dimensional sectoral space of 'causes × effects'. For the '*Alternative Energy*' matrix (Figure 8) the students chose a set of facilitators for the introduction of alternative energy (row headings: subsidies, legislation, feasibility) and an approximation of effects (energy prices, environment, quality of life); hence created approximately a space of 'measures × effects'. None of both matrices has used 'stakeholders' as a dimension.

Summing up, both matrices resemble to the 'input × output' type, but are distorted away from purely logical structure through their embeddedness in real-world issues.

According to the rules (Section 3.1.3 or Ahamer, 2005a), the placement of chips reflects the inclination of teams to discuss a grid cell and hence their implicit *relative weight of these sub-themes*. In the 'Climate Change' case, students placed most weight on 'economy/traffic' and 'environment/traffic' (which coincides with experts' consensus on contributions to climate change). In the 'Alternative Energy' case, students placed most weight on 'energy price/subsidies' and 'quality of life/legislation', which again indicates students' suitable understanding of bottlenecks for real-world solutions.

For both themes, discussions occurred for 4 out of 9 grid cells, with a discussion length ranging from 10 minutes to 23 minutes (see italic text in the grid cells of Figures 7 and 8). Inside the matrix cells, the participating roles are listed in italics above the sub-themes. The winning team is underlined. All discussions for both themes lasted 4–5 hours altogether.

In compliance with the game rules, students representing the other theme were watching the entire discussion (and had the possibility to use PCs standing along the wall of the class for their web based feedbacks). Hereby some of the classical tasks of a trainer such as answering questions, grading, and assessing assignments are structurally transferred to the students, which again underlines the peer-oriented style of SGC.

The above narrative shows that the design of SGC contains *rhythmisation* in four respects:

- *temporal rhythmisation*: imprinted on the game flow by the grid cells that are selected, discussed through (typically for 3–25 min) and voted upon
- *communicational rhythmisation*: changing constellations of participating teams in the active discussion (typically 2–4 teams)
- *argumentational rhythmisation*: switching from one logical combination of row and column (i.e., grid cell) to another, thus switching to other relevancies (typically 4–9 grid cells)
- *role related rhythmisation*: moving from active discussant to monitoring spectator (largely after 2 hours, when changing from inside to outside).

Summing up, the physically most direct link between TA philosophy and the game SGC is the *creation and usage of the matrices* in Level 3.

In SGC, *dialogic problem solving* is the path to do TA. The rhythmised sequence of tasks in Level 3 of SGC guides students on their tedious path of differentiating a complex theme into details and of reintegrating them after having weighted such details (compare Figure 2). Representing 'perspectives' by physically visible 'teams' sitting on tables facilitates perception of the *multi-perspectivist* nature of reality.

5 Results: social skills and social dynamics

5.1 Evaluation of students' skills

Students' performance in all levels of SGC has been good to very good in the eyes of the trainer (= lecturer). Students mastered the academic and social hurdles built into SGC and each one found her or his personal equilibrium between "socially friendly behaviour towards colleagues" and "severe academic judgement of co-competitors' achievements". Overall student performance (as assessed additionally in traditional way by the trainer) and in-depth understanding was clearly better than compared with a more traditional style of the same lectures in the years 1999–2002.

Both critical and encouraging feedback was given to the trainer by students in several anonymous surveys. For the lecturer it is interesting to see that positive performance correlated with the level of satisfaction experienced by participants (on a level of single students and also on a course level: see Table 3). This general finding does not contradict the trainer's constructionist expectations and might well have to do with the result of the very detailed analysis of the first implementation in March 2003, where Schinnerl (2003) acted as participant observer and concluded from her guided interviews with FH students in civil engineering (BBM):

> "Many of the learners were not able to acquire enough knowledge for the game because of the self-directed learning approach, which was the basis for the courses. Competences for self-directed learning appear to be inadequate in the fields of cognition and using resources. However, social interaction skills are very well established. The general conditions had been provided [by the trainer] but not to such an extent that they provided sufficient help for the learners. There was a positive correlation between the provided general conditions, the competence to act and the technical knowledge."

The lecturer in his turn had counted on the supposedly already existing capacities of students; but a mismatch remained, possibly due to a traditional orientation of 'just solve posed questions' for students in more technological curricula.

The trainer's own observations indicate relatively high analytical skills, but possibly low inclination to socialising and coalition-building with students of Industrial Electronics (IEL). A switch from "believing in correct technological facts" to 'handling arguments' seemed a hurdle for some of them. On the other hand, students of Civil Engineering (BBM) exhibited characteristics the other way round (third column in Table 3), they were quick in circumventing rules, formed secret cartels when placing chips or during voting, but played down the relevancy of fact-bound argumentation.

Based on the seven modes of expertise proposed in Section 2.5 it could be concluded here that all students were on their way to master self-guided tasks in some respects (e.g., group formation and circumstantiating basic academic skills during exams) but were still further away from proficiency in more advanced (compare Table 2) disciplines of argumentation like implementing sufficiently accepted consensus in complex technological case studies.

Table 3 Social construction in different disciplines and universities

Discipline	*Satisfaction and contentedness*	*Behaviour*	*Performance*
BBM: civil engineering	Low	Playing with rules, circumventing rules	Low
IEL: electronics engineering	Medium	Obeying rules, 'studying' properly	Medium
USW: environmental systems science	Very high	Working along rules in a self-guided way	High
Summer seminar 2005: Education	Very high	Self-motivated expertise	High

Source: Inspired by Perry and Sanderson (1998, p.282)

5.2 Social dynamics reviewed

In this section, the overall social dynamics of the game SGC is dealt with by means of three external educational assessments listed in Section 4.1. The review by an expert on *social dynamics* (Rauch, 2003) concluded from the first (and still quite experimental) implementation of the controversial discussion in Level 3:

> "All the mentioned points of the 'social analysis' of the game SGC can be seen as a setting introducing 'more than a simulation', namely a mix of real-life agendas and game agendas, to the course of events. – For some this might turn out as an advantage, for some as a disadvantage. In any case, it comes very close to socio-political processes anywhere. – Much though depends on how important the grade to attain is for each individual student. [i.e., student behaviour could be optimised in order to receive many points through cartels of interest at the expense of profoundness of argumentation. G.A.] They learn in at least two dimensions: TA and social processes, or rather local socio-political behaviour and TA-argumentation.

> Therefore, much can depend on
>
> - how the game is introduced and
> - in what background setting it takes place.
>
> A thorough prolog and an equally refined epilog can help to make use of the many learning effects inherent in this grand game."

As outlined above, the 'task' of a procedural shell such as SGC is to 'boost' whomever participating, regardless of the level of skills prevailing at the outset.

Other authors posit 'learning styles' (Wild and Quinn, 1998, pp.77, 78) – a concept that is not followed here. Regardless whether the reader might wish to consider 'learning styles' as alterable or predetermined, SGC feels obliged to *cope with the multitude of student profiles and inclinations*: this is another reason for the rhythmised sequence of inherent communication styles. Why? For the participants, rhythmisation creates very diverse constellations, educational starting points and offered communicative profiles. Consequently the probability is higher for a match with the profile requested by the particular student – as a function of their respective modes of experience. By such increased communicative affinity delivered by SGC dramaturgy, students become better 'glued' to the course.

6 Conclusion

The issue at the core of this paper was useful '*design of social processes*'.

Various social processes are at the core of both '*Technology Assessment*' (TA) and *gaming*. For purposes of engineering education and – more especially – for education in TA, the new negotiation game '*Surfing Global Change*' (SGC) is proposed.

Several interdisciplinary web-based *implementations* of SGC at two universities have been performed, statistically analysed and used as an opportunity to harvest rich *feedback* from students and experts – which in turn gave rise to continuous adaptation and fine tuning of the system of rules, codified in Ahamer (2004b, 2006). Improved *graphic design* was recently added to the implementation on the learning platform WebCT, which mirrors the overall architecture and content of the game.

SGC is a *suite* (= composed series) *of five game levels*. Both academic skills and social skills demanded in a certain level build on the respective achievements in previous levels. The notions of 'social process design' and 'design grammar' are used to illustrate the planned *evolution* of social and intellectual activities along SGC.

SGC is constructed as an evolving, but *rhythmised suite of social borderconditions*, within which gamers find *space to behave*. Taking the example of the parameter 'degree of differentiation into details', such rhythmisation has been illustrated. A generalised graphical notation of 'rhythmisation' is planned for a future paper.

Concluding from the characteristics of 'Technology Assessment', advice is given to permit for *'multi-perspectivism' in engineering education*. This is a necessary means to incorporate all possible (role-dependent) views into a holistic concept in order to strengthen the interdisciplinary tissue of understanding.

Concluding from comparisons with architecture and music, 'design' as a concept should be understood in a universal way as a *compound of temporal, spatial and inter-individual framework conditions that enact processes*.

The novelties of the SGC gaming procedure are:

- *rhythmisation* (regarding time, roles, teams and arguments)
- *five evolving levels* of SGC as a guiding principle
- concentration on and peer assessment of *behaviour* of students.

Didactically speaking, SGC hopes to be largely independent of the level of proficiency a participant exhibits at the outset and concentrates on maximising the 'relative step forward' of a player during the gaming procedure.

As an answer to the question "*which social process design is best for training TA*?", it is found to best place participants into a field of tension (if not multiple fields of tension): Players of SGC have to *equilibrate their social interests* ("be kind to colleagues") and their *cognitive responsibility* ("be severe to competitors in case of shortcomings").

To sum up, in this sense SGC can be seen as 'more than a simulation', namely a "mix of real-life agendas and game agendas" – as one of the evaluators has put it.

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[1]'Surfing Global Change' was invented in 2002 by the first author out of own experience and is his copyright.