Exploring the Engagement and Reflection Model with the Creative Systems Framework

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Abstract

We employ the Creative Systems Framework (Wiggins 2006) to explore the Account of Writing as Creative Design proposed by Sharples (Sharples 1996). The purpose of this exploration is to have a deeper understanding of this proposal and so, be able to analyse computer implementations of it.

Conceptual spaces

Boden (1990) points out that there is a *Conceptual Space (CS)* where creative ideas exist. She suggests that this CS has origin in the culture of the creator and is any disciplined way of thinking that is familiar to (and valued by) a certain social group. Boden (1990) defines a CS as a structured style of thought and she points out that conceptual spaces are normally learned from the culture. For any CS there are rules or constraints which form it and in this CS new ideas (concepts) may be found.

Boden (1990) explains that concepts can be found in a CS by *Exploration* and *Transformation*. She states that by exploring the CS someone may be able to see possible concepts that had not been discovered yet. By transforming the CS its form changes because the rules or constraints have been changed and different concepts may be available to be found.

Writing as a creative design

Sharples (1996) proposes an account of writing as a creative design. Sharples points out that the main part of this account is that writing is a cognitive activity and an open-ended design process that requires tools, resources and setting constraints on goals, plans, etc., but creative writing also requires breaking of such constraints (Sharples 1996).

The writer imposes appropriate constraints that come from a combination of the task itself, external resources, knowledge and experience of the writer.

Sharples explains that it is also necessary to distinguish between novelty and adequacy and creativity to advance in the description of the mechanisms of creative writing. Boden (1990) in her analysis of cognition and creativity explains that in conceptual spaces it is possible to find new ideas. Sharples points out that those ideas, found in conceptual spaces, must be not only novel but also appropriate for the task and the public. Sharples explains that an important part of his account is the description of a set of constraints to generate appropriate content. They constraint the generative system and form what Boden (1990) describes as the conceptual space. A conceptual space limits the scope of the search through long-term memory to the concepts and schemes that are appropriate for the task. It can be restrictive and invoke a flow of conventional ideas, but also provides the source material for creativity (Sharples 1996).

A writing task begins with a given set of constraints. These can be external, such as a topic, previously written material, or a set of editor guidelines. They can also come from the writer, such as the schemes, interrelated concepts, genres and knowledge of a language that form the conceptual spaces of the writer. The task is also restricted by the tools a writer uses and by the context in which the writing occurs. These constraints act together to frame the activity of writing. The success of this task is how knowledge is guided by the restriction so that a successful writer invoke just the right schemes (Sharples 1996).

Sharples explains that there are similarities between the studies of cognition in design and the cognitive theories of creativity in writing. Sharples (1996) explains:

- Design problems are open-ended and can not be fully specified. They do not have a fixed set of goals or a sequence of steps, each of which can be evaluated in terms of their proximity to the goal.
- The design process is endless. There is an inexhaustible amount of possible solutions, and the end of the design process is a matter of criteria. A designer stops when it no longer seems worth the effort to try to improve the quality of the product, or by some external factor, such as running out of time or resources.
- There is no design process that is infallibly correct. There are many different and equally successful approaches, and good designers can control and vary their strategies according to the task.
- The process involves finding and solving problems. The design process does not consist of a clear sequence of stages prior to a finished product, and much of a designer's time is spent identifying and refining the problem. Sharples also summarises this idea by saying the problem is generated while it is being solved.

- Design inevitably implies a subjective value judgement. A designer asks questions and produces products that can only be judged by a subjective evaluation of quality.
- Design is a prescriptive activity. Unlike the process of scientific discovery, where the objective is to describe the world, design cares about what might, could and should be. It prescribes and creates the future, which requires ethical and moral scrutiny.

Primary generators, which are also constraints, are other important components in this account of writing. A primary generator is a powerful idea, but easy to fix that a designer uses to drive and guide the activity (Sharples 1996).

In a writing task, writers often have to manipulate knowledge externally. To achieve this they can use a number of tools, for example, paper or a computer to capture their mental representations in order to be able to modify, transform and order them. This depends on the resources that the writer has available and they are also part of the constraints the process has (Sharples 1996).

Sharples explains that it is important to observe the effect of the environment and tools on the writing task as a design.

Sharples explains that an episode of writing does not begin with a single goal, but with a set of external and internal constraints. These come as a combination of the task, a collection of resources, aspects of the knowledge and experience of the writer, and a primary generator.

As writing progresses, the constraints provide tacit knowledge to guide the writing process. The writer can re-represent some of them in a more explicit way, as a conceptual space to be explored and transformed. The movement between engaged writing, guided by tacit restriction, and more deliberate reflection forms the cognitive motor of writing (Sharples 1996).

Engagement An engaged writer devotes full attention to creating a chain of associated ideas and converting them into text. The working memory is completely dedicated to the task, and the only other deliberative mental activity that the writer can carry out in the text creation exercise is to speak the words out loud (Sharples 1996).

In order to reflect on the text, it is necessary to stop writing, and the result is that the periods of engagement are interleaved with periods of reflection (Sharples 1996).

Reflection Reflection consists of "sitting back" and reviewing all or part of the written material, conjuring up memories, generating ideas by association, forming and transforming ideas, and planning what new material to create and how to organise it. (Sharples 1996).

The cycle of engagement and reflection establishes distinctive rhythms that characterise writing processes. The period of these rhythms can be short, as when a writer looks back over each sentence, as it is written, or longer when a writer rereads an entire piece of writing and plans a thorough revision (Sharples 1996).

Sharples (1996) makes a special distinction between regular writing activity and explicit knowledge manipulation. He explains that it is possible, for example, to produce grammatically correct language without reciting the rules of grammar. But to explore and transform conceptual spaces is necessary to invoke constraints and schemas as explicit entities and work on them deliberately. Sharples (1996) explains that the mind exploits the knowledge that has already been stored, re-enacting tacit procedures as well as explicit structures. The representational redescription provides us with the means to reflect on the experience. It allows us to review an activity, re-cast it as a mental schema and use it to probe long-term memory, recall related schemas, integrate the new knowledge with the previous one and explore and transform it. Sharples (1996) explains that this transition from tacit knowledge to representational redescription is not easy, even for experienced writers.

In the next section the Creative Systems Framework (CSF) (Wiggins 2006) is explained and later this account of writing proposed by Sharples (1996) is analysed in terms of the CSF. Implementation examples of this account of writing explained are analysed with the resulting CSF framework.

Creative Systems Framework

Wiggins (2006) formalises the ideas on creativity expressed by Boden (1990). He argues that at first sight Boden's proposal lacks elements to use it in a consistent way, so he formalised the concepts in Boden's theory so they can be better applied.

Wiggins explains that artefacts are produced by a system (a creator), in a certain context, like P-creative acts explained by (Boden 1990) which are related to the creator's mind and a culture that is familiar to a certain social group. Wiggins points out that novelty and value are important features of artefacts produced by a system in its context and many authors coincide with this (e.g. (Boden 1990; Pérez y Pérez 1999; Ritchie 2007; Colton 2008)).

Wiggins defines different conceptual elements which are important in the analysis of a creative system.

Universe ($\mathcal{U}$) is a multidimensional space, whose dimensions are capable of representing anything and all possible distinct concepts correspond to distinct points in $\mathcal{U}$ (Wiggins 2006). Conceptual Spaces $\mathcal{C}$ defined by cultural agreements and for specific domains, in which concepts may exist, can be located inside the Universe $\mathcal{U}$.

Language ($\mathcal{L}$) is a common language from which framework's rules will be obtained.

Rules ($\mathcal{R}$) is a subset of $\mathcal{L}$ and are the rules which constrain a Conceptual Space $\mathcal{C}$; they define the nature of the created artefacts. In particular, in the societal context, they represent the agreed nature of what a concept is (Wiggins 2006).

Traversing strategy ($\mathcal{T}$) is a subset of $\mathcal{L}$ and is the set of rules which allow us to traverse the Conceptual Space ($\mathcal{C}$). $\mathcal{T}$ defines the way a particular agent produces an artefact in practical terms (Wiggins 2006).

Evaluation ($\mathcal{E}$) is a subset of $\mathcal{L}$ and is the set of rules for evaluation of concepts according to whatever criteria we may consider appropriate, they define the value of artefacts (Wiggins 2006).

The Creative Systems Framework proposal (Wiggins

2006) has some axiomatic points which are independent of the domain or type of the system.

Axiom 1 All possible concepts, including the empty concept, are represented in $\mathcal{U}$, so, $\top \in \mathcal{U}$.

Axiom 2 All concepts c_i represented in $\mathcal{U}$ are different, so, $\forall c_1, c_2 \in \mathcal{U}, c_1 \neq c_2$

Axiom 3 All conceptual spaces are strict subsets of $\mathcal{U}$, so, $\forall i \quad \mathcal{C}_i \subseteq \mathcal{U}$

Axiom 4 All conceptual spaces $\mathcal{C}$ include the empty concept $\top$, so, $\forall i \quad \top \in \mathcal{C}_i$

$\mathcal{R}$ represents the rules which define the nature of the created artefacts. So, $\mathcal{R}$ constraints the Conceptual Space ($\mathcal{C}$) suggested by Boden (1990). Wiggins (2006) explains that by using an interpretation function $[\![.]\!]$ it is possible to choose members of $\mathcal{U}$ which belongs to $\mathcal{C}$, assuming a well formed set $\mathcal{R}$. We get the expression: $\mathcal{C} = [\![\mathcal{R}]\!](\mathcal{U})$

Similarly, for the search strategy $\mathcal{T}$, Wiggins (2006) explains that another interpretation function is needed $\langle\!\langle ., ., . \rangle\!\rangle$ which, given three well-formed $\mathcal{R}$, $\mathcal{T}$ and $\mathcal{E}$ sets computes a function which maps two totally ordered subset of $\mathcal{U}$; c_{in}, and c_{out}. This function operates on members of $\mathcal{U}$ and not just on members of $\mathcal{C}$ because it is necessary to describe and simulate behaviours which are not completely well-behaved (Wiggins 2006). Therefore we get the expression: $c_{out} = \langle\!\langle \mathcal{R}, \mathcal{T}, \mathcal{E} \rangle\!\rangle (c_{in})$

Having different sets; $\mathcal{R}$ for the nature of the artefact, and $\mathcal{T}$ for the search strategy gives the possibility, explained by Wiggins (2006), to have transformational creativity by transforming $\mathcal{R}$ into $\mathcal{R}'$ or $\mathcal{T}$ into $\mathcal{T}'$ or both. This is an important feature because, for example, changing $\mathcal{R}$ is a way to change the constraints of the conceptual space, and it might be called transformational creativity in Boden (1990) terms and is equivalent to a paradigm shift. Changing $\mathcal{T}$ only affects the agent using that $\mathcal{T}$ (Wiggins 2006) but the agreed nature of an artefact remains the same.

Wiggins (2006) points out that in $\mathcal{C}$ there exist $\mathcal{C}_!$ and $\mathcal{C}_?$, concepts discovered and concepts not discovered yet respectively. Given $\mathcal{R}$ and $\mathcal{T}$ sets, some concepts in $\mathcal{C}_?$ may not be accessible, and even changing $\mathcal{R}$ (transformational creativity in Boden's terms), they might remain non accessible. By changing the search strategy $\mathcal{T}$ the elusive concepts in $\mathcal{C}_?$ might be accessible. This means that by transforming the search strategy one may find by exploration concepts $\mathcal{C}_?$ in $\mathcal{C}$. Boden (1990) suggests that transformational creativity is more significant that the explorational one. Wiggins (2006) explains that this formulation shows that this suggestion of Boden might not be true.

Wiggins (2006) explains that Boden's idea of transformational creativity is to change the rules that define the conceptual space. Wiggins defines two sets of rules, $\mathcal{R}$ and $\mathcal{T}$. Then the transformational creativity consists of changing either of them or both.

A syntax checker that selects $\mathcal{L}$ elements which are well formed is necessary. Therefore the transformations of $\mathcal{T}$ or $\mathcal{R}$ will be well formed in terms of any interpreter. Transformation means building new $\mathcal{L}$ subsets of the old ones (Wiggins 2006).

Wiggins (2006) explains that if we use a meta-language, $\mathcal{L}_\mathcal{L}$, for $\mathcal{L}$, which can describe the construction of new members of $\mathcal{L}$ from old ones, we can pair it with an appropriate interpreter, to allow us to search the space of possibilities. $\mathcal{L}_\mathcal{L}$ can be used to describe this task too. Then, we can evaluate the quality of transformational creativity, with some Ω function (Wiggins 2006). Then it could be possible to specify interpreters, $[\![.]\!]$ and $\langle\!\langle ., ., . \rangle\!\rangle$, which will interpret a rule set $\mathcal{T}_\mathcal{L}$ applied to an agenda of potential sequences in $\mathcal{L}$, such an interpreter could work for both $\mathcal{L}$ and $\mathcal{L}_\mathcal{L}$ (Wiggins 2006). Then, the evaluation function Ω, could be expressed as a set of sequences $\mathcal{E}_\mathcal{L}$ in $\mathcal{L}_\mathcal{L}$ and use $[\![.]\!]$ to execute it (Wiggins 2006). The transformational creativity system can now be expressed as an exploratory creative system working at the meta-level of representation (Wiggins 2006).

Wiggins suggests that, for true transformational creativity to take place the creator needs to be in some sense aware of the rules he/she/it is applying. This self-awareness, suggested by (Wiggins 2006), is what makes a creator able to formalise his/her/its own $\mathcal{R}$ and $\mathcal{T}$ in terms of the meta-language $\mathcal{L}_\mathcal{L}$. So without that self-awareness, a creator cannot exhibit transformational creativity (Wiggins 2006).

Wiggins points out that Boden's supposition that creative agents are well-behaved, in the sense that they either stick within their conceptual space, or alter it politely and deliberately by transformation may not be adequate. There are some situations in which agents may have a different behaviour which can be useful to analyse the system, they may also give information to switch to transformational creativity. They are grouped in (Wiggins 2006) into the terms *Uninspiration* and *Aberration*.

Uninspiration occurs in three different forms:

Hopeless uninspiration: there are not valued concepts in the universe.

Conceptual uninspiration: there are not valued concepts in the conceptual space.

Generative uninspiration: the search strategy of the creative agent does not allow it to find valued concepts

These categories are related to the value of the concepts. An agent can not even start working in the first situation. The second one requires redefining the constraints of the conceptual space. The third case indicates that the agent is not able, by the actual search strategy, to find valued concepts. A solution to this could be to modify the search strategy of the agent (Wiggins 2006).

Aberration is a situation where a creative agent is traversing its conceptual space. The strategy $\mathcal{T}$ enables it to create another concept which does not conform to the constraints required for membership of the existing conceptual space (Wiggins 2006).

Wiggins terms this aberration, since it is a deviation from the norm as expressed by $\mathcal{R}$. The choice of this rather negative terminology is deliberate, reflecting the hostility with which changes to accepted styles are often met in the artistic world (Wiggins 2006).

Aberrant concepts are very interesting because they are not part of $\mathcal{C}$ but the system might be able (by $\mathcal{T}$) to find concepts outside the constraints of the conceptual space defined by $\mathcal{R}$. The evaluation $\mathcal{E}$, of this concepts, has to be analysed carefully because, as expressed by (Wiggins 2006) and it was also noted by (León and Gervás 2010), $\mathcal{E}$ should

be capable of scoring the results of $\mathcal{T}$ even when they fall outside the set defined by $\mathcal{R}$.

An Exploration of Engagement and Reflection under the CSF: An ER-CSF Model

Sharples (1996) explains that an episode of writing does not begin with a single goal, but with a set of external and internal constraints. It was shown in section "Writing as a creative design" that constraints can be the task, a collection of resources, aspects of the knowledge and experience of the writer, and a primary generator.

The constraints provide tacit knowledge to guide the writing process and the cycle E-R forms the cognitive motor of writing (Sharples 1996). Now we apply the Creative Systems Framework (Wiggins 2006) to the Engagement and Refection cycle (Sharples 1996)

Universe ($\mathcal{U}$) is a multidimensional space, whose dimensions are capable of representing anything, including the set of written materials or stories.

Language ($\mathcal{L}$) is a common language from which rules will be obtained.

Rules ($\mathcal{R}$) is formed with the set of constraints which form conceptual spaces. As explained by Sharples (1996) the operations a writer performs at each stage are different, so different results are produced at each stage. There will be $\mathcal{R}_E$ and $\mathcal{R}_R$ sets of rules to produce $\mathcal{C}_E$ and $\mathcal{C}_R$, conceptual spaces for Engagement and Reflection respectively.

$$\mathcal{R}_E \rightarrow \mathcal{C}_E \quad and \quad \mathcal{R}_R \rightarrow \mathcal{C}_R$$

Traversing strategy ($\mathcal{T}$) represents the strategy by which an agent produces an output in practical terms, they are the rules which define the way an agent will traverse $\mathcal{C}$. A writer can have different strategies to traverse the space. It was shown in section "Writing as a creative design", that a writer can have a strategy in which he is constantly reviewing the written material or, in other case, reviewing it after a long period of engaged writing. In any case, following Sharples, a writer produces written material through the strategy of an Engagement and Reflection cycle. As the output can be different due to switching frequency between Engagement and Reflection stages and because the operations performed, there are also two sub-strategies, $\mathcal{T}_E$ and $\mathcal{T}_R$:

1. $\mathcal{T}_E$ to traverse the space $\mathcal{C}_E$. When a writer is generating a chain of associated ideas and turning them into text.
2. $\mathcal{T}_R$ to traverse the space $\mathcal{C}_R$. When a writer is reviewing (and possibly making modifications), contemplating (exploring knowledge and transforming conceptual spaces) and planning for the next execution of engagement.

Evaluation ($\mathcal{E}$) It was outlined by Sharples (1996) that design problems are open-ended and can not be fully specified, they do not have a fixed set of goals or a sequence of steps, so, they cannot be evaluated in terms of their proximity to the goal. Sharples (1996) also highlights that a design task inevitably implies a subjective value judgement. Sharples (1996) explains that an engaged writer devotes full attention to creating a chain of associated ideas and converting them into text and nothing more can be done. Even if this is the case, at some point, a decision to switch to a reflective state is made and this might involve some kind of evaluation of the written material, for example, the extension of the material. During the reflective state, a writer reviews the material, contemplates it and makes plans, this involves the use of constraints, to get a set of criteria to evaluate the material. In the same way that there are two sets of rules $\mathcal{R}_E$ and $\mathcal{R}_R$ that define the conceptual spaces for the Engagement and Reflection stages, two sets can also be considered for the evaluation of concepts; $\mathcal{E}_E$ for Engagement and $\mathcal{E}_R$ for Reflection.

Concepts and rules

In a conceptual space $\mathcal{C}$, it is possible to find *concepts*. The proposal of Sharples (1996) does not indicate a particular type of concept to be found in a conceptual space other that written material. Sharples explains that, during Engagement a writer produces a chain of associated *ideas*. During Reflection the material generated in engagement is reviewed and, possibly, modified.

There are different types of constraints in this account to develop new written material, for example: knowledge and experience of the author, materials and resources, the task, etc.. Constraints have particular definitions but it can be said that there is a common language to define them. A convenient language of all constraints L_C could be represented by expression 1.

$$L_C = Language\_of\_Constraints \tag{1}$$

Wiggins (2006) explains that $\mathcal{R}$ and $\mathcal{T}$ sets are needed to have the rules for the conceptual space and the strategy by which it will be traversed. In order to build those sets, we need a common language to define them too. $\mathcal{R}$ and $\mathcal{T}$ are defined by the set of constraints. We can use expression 1 to define a common language.

$$\mathcal{L} = L_C \tag{2}$$

The set of rules $\mathcal{R}$, which defines $\mathcal{C}$, represent the agreed nature of what a concept is. $\mathcal{R}$ is a subset of $\mathcal{L}$ and can be described using (2). For this analysis, this account has two sets of rules; $\mathcal{R}_E$ and $\mathcal{R}_R$, for $\mathcal{C}_E$ and $\mathcal{C}_R$ conceptual spaces. The expression (3) can be produced.

$$\mathcal{R}_E \subset \mathcal{L}, \quad \mathcal{R}_R \subset \mathcal{L} \tag{3}$$

By using an interpretation function $[\![.]\!]$, members of $\mathcal{U}$ which belongs to $\mathcal{C}_E$ and $\mathcal{C}_R$ conceptual spaces are chosen. We get the expression 4

$$\mathcal{C}_E = [\![\mathcal{R}_E]\!](\mathcal{U}), \quad \mathcal{C}_R = [\![\mathcal{R}_R]\!](\mathcal{U}) \tag{4}$$

Sharples (1996) explains that, during Engagement there is no evaluation because the writer devotes full attention to generate the text and therefore it could be said that the set of evaluation rules $\mathcal{E}_E$, for concepts in $\mathcal{C}_E$, is empty. In contrast, during Reflection, there is an active evaluation ($\mathcal{E}_R$) of the written material. Expression (5) can be produced.

$$\mathcal{E}_E \subset \mathcal{L}, \quad \mathcal{E}_R \subset \mathcal{L} \tag{5}$$

There are also two strategies, $\mathcal{T}_E$ and $\mathcal{T}_R$ (Engagement and Reflection strategies respectively), useful to traverse $\mathcal{C}_E$ and $\mathcal{C}_R$ conceptual spaces. $\mathcal{T}$ is a subset of $\mathcal{L}$ and can be described using expression 2. Expression 6 is produced.

$$\mathcal{T}_E \subset \mathcal{L}, \quad \mathcal{T}_R \subset \mathcal{L} \tag{6}$$

Wiggins (2006) explains that an interpretation function $\langle\langle .,.,. \rangle\rangle$ is needed, which given three well-formed $\mathcal{R}$, $\mathcal{T}$ and $\mathcal{E}$ sets maps two totally ordered subset of $\mathcal{U}$; c_{in}, c_{out}. The interpretation function is one, but there are two different sets of rules constraining the conceptual space $\mathcal{R}_E$ and $\mathcal{R}_R$, two sets $\mathcal{T}_E$ and $\mathcal{T}_R$ for the Engagement and Reflection search strategies and two sets $\mathcal{E}_E$ and $\mathcal{E}_R$ for evaluation of concepts. So, given a c_{in} input subset of $\mathcal{U}$, it is possible to obtain outputs (subsets of $\mathcal{U}$).

$$\begin{aligned} c_{out\_Engagement} &= \langle\langle \mathcal{R}_E, \mathcal{T}_E, \mathcal{E}_E \rangle\rangle (c_{in}) \\ c_{out\_Reflection} &= \langle\langle \mathcal{R}_R, \mathcal{T}_R, \mathcal{E}_R \rangle\rangle (c_{in}) \end{aligned}$$

These functions can operate on members of $\mathcal{U}$ and not just on members of $\mathcal{C}_E$ or $\mathcal{C}_R$. They can describe and simulate behaviours which are not completely well-behaved as suggested by Wiggins (2006).

Aberration in ER-CSF

Wiggins (2006) proposes the term aberration for the situation when an agent is able to create by $\mathcal{T}$ another concept which does not conform to the constraints ($\mathcal{R}$) required for membership of the conceptual space. Sharples (1996) does not give a complete definition of the rules that comprise the conceptual space. In fact he explains that this set of rules depends on the writer and the particular constraints for a particular task. Sharples (1996) points out that, some writing displays such radical originality that we call it creative. Here, this "radical originality" could be a behaviour where the product does not conform to the constraints of the conceptual space.

Uninspiration in ER-CSF

For this account of writing, there is no specific definition of conceptual spaces. It depends on the writer to define a set of constraints to define the conceptual space, and also the strategy of the writer.

Sharples (1996) explains that, for example, the resources the writer uses; paper, pencil, etc., can affect the writing task. When there is a problem with one of the resources, that problem can block the writer if there is no alternative available. This could be an example of generative uninspiration explained by Wiggins (2006), where the strategy does not allow the writer to find valuable concepts in the conceptual space and needs to be changed.

Implementation examples

Example 1: MEXICA

MEXICA is an implementation of the computer model of creativity E-R proposed by Pérez y Pérez (1999).

The main goal of MEXICA is to produce novel and appropriate short stories as a result of an Engagement-Reflection cycle without the use of predefined story-structures which was built with many modifiable parameters to experiment with the process of creating a new story plot (Pérez y Pérez 1999).

MEXICA needs two inputs provided by the user: a set of Primitive Actions (PA) and a set of Previous Stories (PS).

MEXICA has a number of constraints, they will form the conceptual spaces and also define the strategies to build a story.

They are divided in the following categories:

Context Constraints are structures that represent the state of the current story (Pérez y Pérez 1999).

Knowledge Constraints are constituted by the experience, knowledge and beliefs of the writer.

Guidelines constrain the material to satisfy the requirements of novelty and interest (Pérez y Pérez 1999).

General constraints include rhetorical and content constraints not included in the previous classifications. They are formed by a set of requirements that must be satisfied by all events retrieved from memory and are necessary for MEXICA to operate correctly (Pérez y Pérez 1999).

In MEXICA a story is a sequence of events or actions which are coherent and interesting. An action has pre-conditions and post-conditions, useful to give coherence to a story and to know the consequences of the execution of an action respectively.

When an action is executed, consequences arise and they generate a story context. Story contexts are useful in MEXICA because they linked an action with the next one.

Having an action linked to the next is not enough. In MEXICA it is also needed to link an action with the previous one in order to guarantee coherence, this is how pre-conditions are taken into account. In MEXICA a coherent sequence is that where all preconditions of all actions are satisfied. Here we have an important concept in MEXICA: *coherence*. Coherence is a property of stories and they can only be coherent or non-coherent at a time.

Engagement in MEXICA During Engagement a sequence of actions linked by story contexts is produced. MEXICA retrieves possible next actions from memory using story contexts. Engagement selects one of the actions to continue the story appending it to the story in progress (Pérez y Pérez 1999).

During Engagement MEXICA does not verify if the story actions satisfy pre-conditions, so sequences of actions with unsatisfied pre-conditions might be produced (potentially non-coherent stories).

Reflection in MEXICA In contrast with Engagement, Reflection verifies pre-conditions for each action in the story in progress in order to produce a coherent story. When unfulfilled pre-conditions are detected in the story in progress, MEXICA fetches an action whose post-conditions satisfy such unfulfilled pre-conditions and inserts it. The process is repeated if new actions have unsatisfied preconditions (Pérez

y Pérez 1999) During Reflection, only coherent stories can be produced.

MEXICA also implements heuristics to test if the story in progress is interesting. MEXICA assumes that the stories in the set of PS supplied are interesting and so its Tensional Representation is a good example to follow (Pérez y Pérez 1999).

Boden (1990) suggests that novelty is one important characteristic of creative acts. Novelty is also considered in MEXICA and during Reflection, there are rules to assess novelty. MEXICA verifies if the material produced during the Engaged state resembles too much any of the tales in the set of PS (Pérez y Pérez 1999) and if this is the case MEXICA changes the search strategy.

Example 2: Dev E-R

Dev E-R (Aguilar and Pérez Pérez 2015) (Developmental Engagement-Reflection) is a computational model that, inspired by Piaget's theory, simulates the assimilation-accommodation adaptation process. It is implemented with the computer model of creativity Engagement-Reflection. This model simulates adaptation as a creative activity.

In Dev E-R, a development agent is implemented to simulate the adaptation processes to a particular environment. The agent is initialised with basic knowledge structures called schemas, which represent innate behaviours observed in newborns. It is also capable of creating new knowledge structures as a consequence of its interaction with the environment (Aguilar and Pérez Pérez 2015). The objects with which it interacts have a number of characteristics the agent can sense (Aguilar and Pérez Pérez 2015).

When the agent begins to operate it sees objects as static or in-motion luminous spots which have a position within the field of vision. The spots detected are used to create an internal representation of what the agent sees. This representation is called the current context (Aguilar and Pérez Pérez 2015).

At the beginning the agent can not recognise all the visual characteristics of objects, contexts can only describe bright spots appearing, moving and disappearing. These contexts are then used to build schemes. Eventually, through interaction with their environment, the agent acquires the ability to see spots not only as luminous things, but as visual elements with different colours and sizes. Whenever an object enters the field of view of the agent, the values of the variables representing the characteristics of the object increases in one. When the value of the variable associated with any of the differentiated colours or sizes reaches a certain predefined value N, then it is said that such a characteristic has sufficient stimulation and the agent acquires the ability to recognise it and use it to construct its knowledge structures (Aguilar and Pérez Pérez 2015).

The current context is a structure composed of 3 parts: (1) the characteristics of the object that is in the centre of attention of the agent (colour, size, movement and position), (2) the affective responses, emotional states and motivations triggered by such an object, and (3) current expectations of the agent (Aguilar and Pérez Pérez 2015).

Dev E-R schemes are knowledge structures that simulate the sensorimotor schemes, which is a psychological construction that gathers together the perceptions and associated actions involved in the performance of a behaviour. It includes knowledge about the context in which the behaviour was performed, as well as expectations about its effects (Aguilar and Pérez Pérez 2015).

The agent has adaptation mechanisms to simulate assimilation, accommodation and cognitive equilibration processes. They represent its core component, since they allow it to develop cognitively through interaction with the virtual world. This is done either by modifying its perception of the environment so that it fits the current knowledge (adaptation by assimilation) or by modifying and producing new knowledge when it does not match reality (adaptation by accommodation). This model simulates adaptation as a creative activity (Aguilar and Pérez Pérez 2015).

The Dev E-R model has two ways of using and building knowledge of the agent: (1) automatically, through Engagement, and (2) analytically through Reflection (Aguilar and Pérez Pérez 2015).

Engagement in Dev E-R Engagement takes the current context and use it as a cue to probe memory in order to match a scheme that represents a situation similar to the current one. If the current context matches more than one scheme, the system selects only one of them. When a scheme is matched, the agent executes the associated action. Then, the agent perceives its world again, updates the current context and the cycle continues If the agent can not associate any schema an impasse is declared. In this case, it switches to Reflection (Aguilar and Pérez Pérez 2015).

Reflection in Dev E-R During Reflection, the agent tries to analyse the current situation and, with the help of some pre-defined strategies, tries to deal with the unknown situations (Aguilar and Pérez Pérez 2015). In Dev E-R, accommodation implies the creation of new schemes and the modification of existing ones as a result of dealing with unfamiliar situations (Aguilar and Pérez Pérez 2015). The creation and modification of the schemes is carried out by means of the following methods: generalisation or differentiation. The process of generalisation takes place in two situations: (1) when the agent recovers an object of interest by chance and then it generalises that sole experience in an abstract schema; and (2) when the agent detects that the same action can recover various objects with different features and then it generalises this knowledge in an sole schema (Aguilar and Pérez Pérez 2015).

As a result of development of the agent, the search mechanisms during Engagement change to adapt to the increased number of experiences.

MEXICA and Dev E-R under the ER-CSF

Two implementations of the Engagement-Reflection model have been presented. Now they are analysed based on the ER-CSF model presented in section "An ER-CSF Model".

Sharples (1996) explains that a writing process depends on a set of external and internal constraints that will guide the process. The Engagement and Reflection cycle forms

the cognitive motor of this process considering that set of constraints.

Also, there are some concepts presented in the ER-CSF model that should now be related to the implementations examples.

Universe ($\mathcal{U}$) is the multidimensional space, whose dimensions are capable of representing anything. for Sharples (1996) the set of written materials is the important one. In MEXICA (Pérez y Pérez 1999), is the set of short stories about the Mexicas. In Dev E-R (Aguilar and Pérez Pérez 2015) is the set of behaviours of the agent.

Language ($\mathcal{L}$) is a common language from which rules will be obtained. This language changes for each case because they are not in the same domain. Sharples' (1996) account and MEXICA could be more related because they generate written materials but they do not consider the same kind of constraints, so the language is different.

Rules ($\mathcal{R}$) is formed with the set of constraints which build conceptual spaces. For Sharples (1996), the operations a writer performs in Engagement and Reflection are different, and so are the results produced at each stage. In MEXICA, there are rules for the operation of the system which form conceptual spaces of coherent or non-coherent stories. Also, some constraints are useful to an specific stage. In Dev E-R the agent deals with a set of constraints which include; objects, properties of those objects, expectations, actions the agent can perform, a number of initial basic behaviours which will be developed, etc. Engagement deals with the interaction with the context related to familiar schemas (behaviours) reinforcing the stimuli of a property or the pleasure over a particular situation. Reflection deals with unfamiliar situations from which the system will create new schemas or synthesise them.

In any case, the set of constraints which define conceptual spaces are different for Engagement and Reflection and also the processes are different in each stage and therefore they produce different results. So, following the ER-CSF model, there are $\mathcal{R}_E$ and $\mathcal{R}_R$ sets of rules to produce two different conceptual spaces $\mathcal{C}_E$ and $\mathcal{C}_R$, for Engagement and Reflection respectively.

Traversing strategy ($\mathcal{T}$) represents the strategy by which an agent produces an output in practical terms. For Sharples (1996), a writer can have different strategies due to knowledge but also materials. In MEXICA (Pérez y Pérez 1999), the previous knowledge is important but not the material or resources. In contrast, Dev E-R (Aguilar and Pérez Pérez 2015) uses a representation of objects which are the surrounding context of the agent and they may represent its resources or materials, the previous knowledge is also important but at the beginning is very limited, as the process goes on it is incremented. $\mathcal{T}$ are the rules which define the way an agent will traverse $\mathcal{C}$.

MEXICA produces a story and Dev E-R produces the knowledge of the agent, both through the strategy of an Engagement and Reflection cycle, as explained in section "Writing as a creative design". The outcomes of each stage can be different because they do not perform the same operations to continue a story in progress. So, there are two sub-strategies, $\mathcal{T}_E$ and $\mathcal{T}_R$.

1. $\mathcal{T}_E$ to traverse the space $\mathcal{C}_E$. For MEXICA, when the system is working in the Engagement state and when actions are being appended using story contexts and no pre-conditions of any action are verified and when the agent faces familiar situations and updates existing schemas for Dev E-R.
2. $\mathcal{T}_R$ to traverse the space $\mathcal{C}_R$. For MEXICA, when, in order to produce a coherent story, pre-conditions are verified and when Engagement is not able to retrieve actions from memory to continue the story in progress and an impasse is declared. And for Dev E-R when the agent faces unfamiliar situations and it needs to adapt to that situation by creating schemas or synthesising them.

Evaluation ($\mathcal{E}$) It was explained by Sharples (1996) that no specific goals are established and that there is no specific evaluation function of the material because the design task is an open-ended problem. But he also explains that at some point some evaluation should be made. MEXICA does not have evaluation rules during Engagement but it has rules to evaluate novelty and interest implemented in Reflection. Depending on the result of the evaluation, guidelines might be updated and the strategy $\mathcal{T}_E$ might change (this may be seen as strategy-transformation, $\mathcal{T}$-transformational creativity in Wiggins' (2006) terms). Dev E-R has rules to evaluate novelty and adaptation of the agent to the virtual world, but in contrast with the ER-CSF model, this does not happen in a particular stage. We can say that both stages have the same set of rules for evaluation. MEXICA in the original model and Dev E-R do not have specific goals to evaluate the outputs, but Pérez y Pérez (2015) introduces a new model for MEXICA for evaluating its outputs. In this new model two instances of MEXICA work together to produce a story, they have different sets of PS but when the story is finished they incorporate the new story to their knowledge structures, so, they change, producing more structures or widening the existing ones, This is a relevant characteristic and will be analysed in a future work but for this analysis, we will continue using the original model in order to have a solid starting point.

As explained in section "Writing as a creative design", there could be evaluation during each stage, so, two sets can also be considered for the evaluation of concepts; $\mathcal{E}_E$ for Engagement and $\mathcal{E}_R$ for Reflection.

Concepts and conceptual spaces are different for this examples, but they all need the rules to build the conceptual spaces from their particular definition of a concept. A common language is needed to define the rules of this model. From this language we can be able to define the conceptual space(s), strategies and evaluation rules.

From section "An ER-CSF Model" we can use expression 1 to produce a common language even if the constraints are different for this examples. We also can generate the sets of rules $\mathcal{R}_E$ and $\mathcal{R}_R$ with the expression 3.

With the sets of rules $\mathcal{R}_E$ and $\mathcal{R}_R$ defined, we can use an interpretation function to chose members of $\mathcal{U}$ which belongs to $\mathcal{C}_E$ and $\mathcal{C}_R$ conceptual spaces as it was shown in expression 4.

Following the description in section "An ER-CSF

Model", we can produce sets of rules for evaluation. Sharples (1996) explains that, during Engagement there is no evaluation because the writer devotes full attention to generate the text and therefore it could be said that the set of evaluation rules for Engagement $\mathcal{E}_E$, for concepts in $\mathcal{C}_E$, is empty and the same can be said about MEXICA, so we get $\mathcal{E}_E = \varnothing$. These are special cases we can get from expression 5 in section "An ER-CSF Model". And finally we can get search strategies for both systems using expression 6.

Aberration Pérez y Pérez (1999) explains that in MEXICA a story is a sequence of actions, but it is also important that the sequences of actions are logical and coherent. A logic and coherent sequence of actions is that where the preconditions of all actions in the sequence are satisfied (Pérez y Pérez 1999).

In Engagement there is no guarantee to produce a coherent story. Furthermore, when Engagement receives a coherent story from Reflection, it appends a new action to the story and that operation can modify the story producing a potentially non-coherent story. When a non-coherent story is generated, that story does not conform to the constraint of $\mathcal{R}_R$ and is, therefore, an aberrant concept for Reflection.

What is important to notice here is that as part of the MEXICA process the system is exploring options out of the scope of the main objective of MEXICA (out of the scope of $\mathcal{C}_R$ too, therefore aberrant concepts) which is to produce coherent stories.

In Dev E-R the concepts that can be generated can only refer to the virtual world in which the agent is developing, the objects in the world and their characteristics, and also to the action the agent can perform. There are many variations but all concepts that can be generated meet the rules of the conceptual space, so it is not possible to find aberrant concepts.

Uninspiration In MEXICA and Dev E-R, when Engagement is not able to find actions or schemas related to the current context an impasse is declared. The search strategy $\mathcal{T}_E$ is not being able to create a new concept. This can be seen as uninspiration in Wiggins' (Wiggins 2006) terms. When the uninspiration is due to the generative process it can be fixed by changing the strategy $\mathcal{T}$. MEXICA and Dev E-R can break an impasse by switching to Reflection and they both change the current context adding a new action or applying a change in the state of the agent (e.g. to move its head) or its knowledge.

Once Reflection has changed the context, the system switches to Engagement but now it can be considered that strategy $\mathcal{T}_E$ has changed because different knowledge constraints and, guidelines for MEXICA, are available.

This implementation examples are basically the same in terms of the model but have differences regarding the evaluation rules, specifically $\mathcal{E}_E$. MEXICA has an empty set of evaluation rules for engagement (the same as Sharples' (1996) account), but Dev E-R has the same set of rules for Engagement than for Reflection $\mathcal{E}_E = \mathcal{E}_R$. They are also different because Dev E-R can not generate aberrant concepts and MEXICA can.

Conclusions

Sharples' (1996) proposal, in which it is explained that, a writing process is guided by constraints and by an Engagement and Reflection cycle has been analysed using the Creative Systems Framework (CSF: Wiggins 2006) to achieve a better understanding of this model and to better apply it in computer systems.

Two examples have been shown that implement in a computational system an Engagement and Reflection cycle that guided by a set of constraints produce a result. The examples shown have been analysed based on the review of Sharples' proposal under the CSF. We conclude that the model product of this analysis shows particular characteristics of operation for each stage of the cycle and therefore the results are not always the same. Also, the constraints are used differently in each stage and that affects the results.

This analysis shows a clear differentiation between the conceptual spaces, rules that define them, strategies and evaluation for Engagement and Reflection. This differentiation makes an important contribution in the systems since it allows the system to explore conceptual spaces whose members may not belong to its conceptual space. It is also important to notice how one stage can modify the way the other operates, changing the constraints.

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