Experience Report submitted to IEEE Software

Provoking Creativity: Imagine What Your Requirements Could be Like

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Abstract

Requirements engineering research, with its focus on elicitation, analysis and management, offers little to support the creation or invention of requirements. This paper reports the use of innovative techniques to encourage creative thinking about requirements for an air traffic control system. It describes results from 3 creativity workshops and lessons learned to integrate creativity workshops into structured requirements processes.

Keywords

Requirements engineering, creativity workshops.

1. Introduction

Requirements engineering is not recognised as a creative process (e.g. Nuseibeh & Easterbrook 2000). However, the emergence of new systems and products means that stakeholders increasingly create and invent ideas that they express as requirements. It is a trend that requirements engineering, with its focus on elicitation, analysis and management, has yet to grasp fully.

This experience paper reports techniques that were applied to encourage creative thinking during the requirements process for a software-based system in a naturally conservative domain – air traffic management (ATM). It describes the application of unusual theories, such as analogical reasoning from cognitive science, to underpin the use of these techniques, and reports basic results and lessons learned. It focuses on the creativity techniques applied and demonstrates them with examples from the ATM domain.

2. Determining requirements for the CORA-2 system

We worked with Eurocontrol, the organization overseeing European air space, to design and implement RESCUE, a process for determining stakeholder requirements. RESCUE was applied to CORA-2 (Conflict Resolution Assistant), a system that will provide computer-based assistance to air traffic controllers to resolve potential conflicts between aircraft. CORA-2 is a complex socio-technical system in which air traffic controllers will depend on the new computer system to do their work. CORA-2 requirements were expected to specify how controllers should work and interact

with the software system as well as how the software system shall function, for example how to increase automated support for controllers without deskilling them.

The CORA-2 team consisted of one manager, 2 requirements engineers, 2 air traffic controllers who acted as domain experts, 1 human factors expert and 1 technical expert. It applied the RESCUE process to establish the stakeholder requirements for the CORA-2 system. Prior to the workshops the team acquired 50 stakeholder requirements from brainstorming and interview sessions.

Next, three one-day creativity workshops were held over a two-month period to generate requirements and design ideas for CORA-2. Each workshop involved between 16 and 20 team members and stakeholders (managers, air traffic controllers and technology experts). The design of creativity periods in each workshop was based on established creativity theories from cognitive and social psychology and artificial intelligence. The workshops were designed to encourage ideas based on the following definition of creativity from cognitive psychology – "*the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task and constraints)"* (Sternberg & Lubart 1995). The use of creativity theories selected from a wider review of the creativity literature distinguished the CORA-2 workshops from other brainstorming processes.

2.1. Creativity theories applied to the workshops

We applied elements of Osborn's Creative Problem Solving (CPS) model (Isaksen & Dorval 1993) to structure each workshop. The model proposes iterative divergence from then convergence on ideas to find objectives, facts and solutions. This well-established creativity model provided the framework for ordering workshop activities. We designed each half-day period to support divergent activities to generate a large number of ideas, and convergent activities to reduce this number and concretize ideas. This contrasts with the structure of brainstorming and the theoretical focus on RAD workshops on group dynamics and consensus building (e.g. Floyd 1989) rather than how to encourage creative thinking per se.

We applied existing theories of creative processes (e.g. Hadamard 1954, Poincare 1982) to facilitate divergence and convergence. Four processes are essential to creative thinking: preparation, incubation, illumination and verification. Incubation is needed to handle complexity - during this relaxing period, people unconsciously and consciously combine ideas with a freedom that denies linear and rational thought (Boden 1990). During the subsequent and shorter illumination phase, a creative or innovative idea suddenly emerges, often at the most unlikely time in the most unlikely place. This 'eureka' effect has been widely reported in creative problem solving. Creative process theories were adopted because their finer-grain processes enabled us to decompose divergence and convergence in the CPS model into sequential workshop activities. The deliberate use of relaxed incubation periods, during which participants listened to music or looked at pictures, was another characteristic that distinguished our workshops from brainstorming activities which emphasize illumination.

The three workshops were also designed to encourage different types of creative thinking – explorative, combinatorial and transformational (Boden 1990). The first workshop was designed to encourage exploratory creativity, in which people explore

the space of possible ideas to create new ones. Although similar to brainstorming, our innovation was to encourage analogical reasoning – common in creative domains – to generate new ideas. Researchers have investigated analogical reasoning to support requirements reuse (e.g. Massonet & van Lamsweerde 1997) and shown that people can exploit analogies if helped to understand them (Maiden & Sutcliffe 1992). Based on this previous success, we encouraged the participants in the CORA-2 workshops to go further and use knowledge transferred from the non-ATM domains to provoke creative thinking about requirements and high-level designs in the ATM domain.

The last 2 workshops were designed to encourage combinatorial creativity, which is the creation of new ideas from a combination and synthesis of existing ideas. Boden (1990) states that it is characterised by the improbability of the combination, or the surprise encountered when such an unusual combination is presented. Most existing techniques decompose requirements to make them more precise and easier to understand. We adopted combinatorial creativity in the 2 workshops to challenge these traditional trends to decompose and distinguish the workshops from other approaches.

The last 2 workshops were also designed to encourage transformational creativity. During transformational creativity people change the solution space in a way that things that were considered impossible are now possible (Boden 1990), for example by challenging pre-conceived constraints and exploring new solutions to existing problems. During the third workshop there was a deliberate attempt to understand and sometimes transform the current constraints on the CORA-2 system by exploring elements of the solution space.

Figure 1 shows how the different creativity theories were combined in the design of each CORA-2 workshop. Stakeholders were guided to diverge from then converge on ideas during half-day workshop periods divided into idea preparation, incubation, illumination and verification processes, with different creativity techniques enabling idea incubation and illumination.

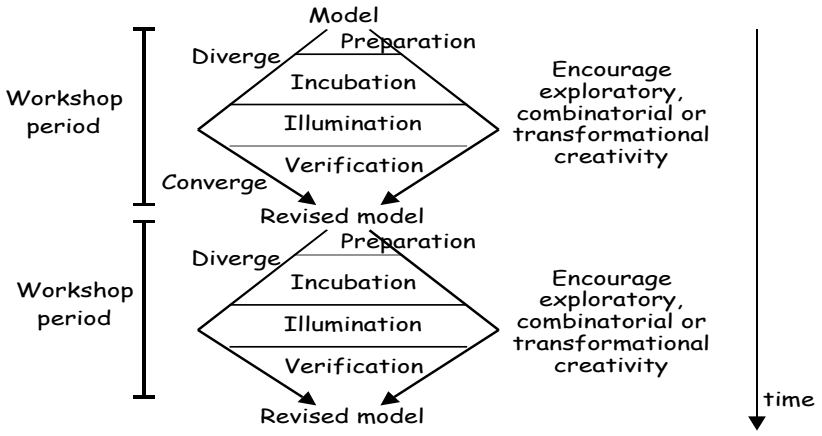

Figure 1. The basic structure of creative periods during a CORA-2 workshop

We did not adopt other established creativity techniques such as cultural probes (Gaver et al. 1999). On reason was that the CORA-2 workshops did not provide direct access to the controller's work environment, which undermined the use of the probes. In addition, RESCUE required the workshops to produce an objective set of

CORA-2 requirements and design ideas, in contrast to an impressionistic account of beliefs and desires sought using probes.

3. The creativity workshops

RESCUE did not mandate any models or requirements to be input into the first workshop. After the first workshop the facilitators maintained a regular e-mail dialogue between the workshops to encourage them to discuss requirements and ideas. The facilitators aimed to create a distributed community.

One of the workshops' most notable features was to invite experts from domains that have similarities (not always obvious!) to aircraft conflict resolution to talk about their domains and encourage different types of creativity.

3.1. Exploratory creativity in the first workshop

To explore new ideas for conflict resolution we invited a textile expert and a musician to talk about Indian textile design and the composition of modern music. Participants were encouraged to form analogies between these domains and ATM, then to generate new ideas about conflict resolution using the analogical elements in textile design and music. These two analogies were carefully selected prior to the workshop based on domain analyses undertaken by the facilitators and examination of the Operational Concept of Use document that had already been developed for CORA-2. In all 3 domains – CORA-2, textile design and music composition, people work with tools to construct and test complex solutions – conflict resolutions, textile patterns and pieces of music. We selected textile design to use different qualities of textile patterns to trigger creative thinking about conflict resolutions. We selected music composition to exploit how a musician composes and tests a piece of music to trigger creative thinking about how an air traffic controller generates and tests conflict resolution strategies.

To encourage incubation, experts presented and answered questions on their topics of expertise. The aim was to encourage participants to unconsciously and consciously form analogical mappings such as those listed in Table 1. One facilitator then encouraged the participants to externalize these analogical mappings. Some analogical mappings were obvious – the musical piece maps to the conflict resolution – whereas others are less so – the style of the piece maps to the resolution strategy.

ATM domain	Textile domain	Music domain	Generalisation
Air traffic controller	Textile designer	Music composer	A human agent seeking to achieve a solution to a problem
Aircraft conflict	Textile design problem	Composition problem	A problem state encountered by the human agent requiring the use of the tool to resolve the problem
Conflict resolution	Textile pattern	Musical piece	The solution to the problem
Resolution strategy	Style or genre of the textile pattern	Musical style	A reusable abstraction that defines the characteristics of the solution type and discriminates it from other types.
Resolution	Pattern features	Musical notes	Elements of the solution

details	such as motif & layout		
CORA-2 system	_____	Musical instrument	The tool that is used by the human agent to solve the problem

Table 1. Some analogical mappings between the ATM, textile and music domains.

The facilitators then encouraged a period of illumination. During illumination, participants used analogical mappings to discover new CORA-2 requirements and ideas. The facilitators encouraged participants to consider one mapping at a time, transfer attributes of the mapped concept (e.g. the texture of a fabric or the structure of a musical piece) into the ATM domain, then to generate new CORA-2 requirements and ideas from these elements. Consider the following example from the first workshop. Participants reported that one of the textile designs was *elegant*, in other words *simple, beautiful* and *symmetrical*. These attributes were transferred to the ATM domain to generate the requirement for elegant resolution strategies, that is strategies that are simple (minimum manouevres) and give pride to the controllers who implement them. In addition, the participants perceived elegance differently. Again this attribute, subjective perception of elegance by the human agent, was transferred to the ATM domain to generate the requirement to accommodate different controller styles during conflict resolution.

3.2. Combinatorial creativity in the second and third workshops

We encouraged combinatorial creative thinking once many new ideas had been generated. Head of talent at toy manufacturer Lego provoked creative thinking by randomly introducing items into conflict resolution scenarios. Participants were divided into groups of 3, then asked to develop worst-case aircraft conflict scenarios. Every 10 minutes each group was given a new object at random (e.g. a toy frog, pair of binoculars, perfume or torch) to include in the scenario. The results were unusual scenarios represented as collages shown in Figure 2 and used during illumination to generate ideas about how CORA-2 would handle these conflicts.

Figure 2. Aircraft conflict storyboards generated by the participants

We encouraged combinatorial creativity during the third workshop by inviting a fusion chef to talk about combining unusual ingredients, share ingredients for tasting,

and demonstrate fusion cooking with lunch that reflected different but complementing ingredients. During illumination, the facilitators encouraged participants to investigate pairs of existing CORA-2 requirements and ideas to create new ones from unforeseen combinations and write them on RESCUE idea cards. For example two original ideas from the second workshop, that *air traffic controllers should maintain an accurate mental model of the air space*, and that *CORA-2 shall offer new types of situational display to air traffic controllers*, were combined to generate the new requirement, that *CORA-2 shall allow air traffic controllers to re-wind and fast-forward aircraft movements to develop their mental models of the air space before taking responsibilities for decisions that they will make*. In another example, two ideas from the first and second workshops, *that manufacturers equip aircraft with the Airborne Separation Assistance System (ASAS)*, and that *pilots in the cockpit have the same notion of conflict as do air traffic controllers in the tower*, led to the idea that *air traffic controllers shall use data link to send information about and hence the delegation of a resolution to the pilot.*

3.3. Transformational creativity in the second and third workshops

The facilitators encouraged participants to change the CORA-2 solution space to make ideas that were once considered impossible possible. During incubation periods participants listened to presentations from domain experts with closer associations to the ATM domain. An information visualisation expert presented new solutions for displaying complex information at workstations, and a systems engineer explained how to adopt state-of-the-art approaches to complex systems engineering. The participants then worked in small groups with candidate solutions provided by the experts to generate new solutions. Examples included *controller displays that were blank until conflicts were detected*, and *tactile manipulation of aircraft on the display screens*. Although not all ideas could be implemented in CORA-2, their essence led participants to discover a large number of less radical requirements and designs, such as *transferring knowledge on cockpit design to the design of the controller working position*.

3.4. Other creative activities

Each workshop started with activities intended to establish an environment more conducive to creative thinking:

- Explaining why creativity is difficult, so that participants knew the challenges that they face;
- Balloons available, to encourage participants to play and interact;
- Shouting sessions to remove inhibitions and promote teamwork, and music to relax;
- Lunchtime exercises, to encourage participants to see creative thinking as continuous.

We also applied additional techniques to support different creative processes:

- Explicitly having participants remove constraints from ideas, to open up the candidate requirements space;
- Using the explorer, artist, judge, and warrior roles to focus the participants on different creative processes (van Oech 1986);
- Playing each other's controller, pilot and manager roles, to generate ideas from unencumbered perspectives;

- Making all ideas visible to participants by posting ideas on cards;
- Swapping ideas between groups to encourage combinatorial creativity.

In a fourth CORA-2 workshop participants selected and ranked ideas. Participants ranked ideas as relevant to either CORA-2 system, its successor CORA-3 system, or future (CORA+) as yet unspecified systems. Other categories such as *valued*, *very valued* and *very-very* valued were used to promote playfulness when exploring the ideas.

4. The Effectiveness of the Workshops

The 3 workshops generated 201 new ideas for the CORA-2 system. Table 2 shows the numbers of new ideas generated during each workshop. The low total from the first workshop was because the facilitators also spent time discovering important constraints and scoping CORA-2. The second workshop generated the majority of the ideas. The third workshop produced fewer new ideas but a further 46 ideas were generated by participants after the workshop.

Workshop	Total number of ideas	Total number of constraints	Total of valued ideas	Total of very valued ideas	Total of very-very valued ideas	Ideas relevant to CORA-2	Ideas relevant to CORA-3	Ideas relevant to CORA+
1st workshop	20	58	N/A	N/A	N/A	N/A	N/A	N/A
2nd workshop	115	0	20	12	5	N/A	N/A	N/A
3rd workshop	18	0	3	6	5	11	3	1
4th workshop	46	0	5	24	7	44	2	0

Table 2. The total numbers of design ideas and constraints reported at each workshop, the total number of *valued*, *very valued* and *very-very valued* ideas per workshop, and their relevance to CORA-2, CORA-3 or future CORA+ systems.

A retrospective analysis by the authors of these 201 ideas revealed that only 54 could be described as stakeholder requirements – desirable, solution-independent properties of the future system. The remaining 147 encapsulated differing degrees of design and process knowledge. Nonetheless, the 201 requirements and design ideas provided a baseline for writing more precise use cases and generating more precise scenarios that, in turn, enabled more effective requirements acquisition and specification using ART-SCENE (Mavin & Maiden 2003).

5. Key Lessons Learned

In this section we describe 7 problems encountered during the workshops and how these problems can be overcome in future projects.

5.1. Analogical reasoning is rewarding but difficult – even with support

Problem: Workshop participants found it difficult to exploit the analogies. Participants only generated 20 ideas in the first workshop. In hindsight this should not have been surprising – studies from cognitive science revealed that analogical reasoning with unfamiliar classes of domain was difficult without prior learning (e.g. Gick & Holyoak 1983). What was disappointing was that our facilitation was not more successful.

Solution: To encourage analogical learning during incubation, explain analogies to participants with simple analogical examples in an order during them to learn the important underlying abstractions, for example the generic compose-and-test process in music composition and conflict resolution. Note that all of this takes time, which leads on to the next lesson.

5.2. Illuminating analogical ideas takes time

Problem: We designed longer time periods for idea incubation and shorter periods for subsequent idea illumination. Illumination activities rarely lasted more than 30 minutes but were not long enough to illuminate a large number of analogical ideas.

Solution: Treat creative requirements engineering as a learning process, so allow time for learning to take place. Design each workshop to last at least 2 days, and encourage participants to incubate ideas both inside and outside scheduled workshop times. Adopt more flexible planning to respond to unanticipated new threads of creative thinking that take on a momentum of their own – this was often when the most effective creative thinking took place. Avoid dynamic short-term exercises as they cut dynamic creative thinking short. Instead, facilitators should be able to apply a range of creativity tasks in response to threads of creative thinking. One option is to select tasks based on a categorization using van Oech's (1986) creative roles or Boden's (1990) creative processes.

5.3. Interleave creative processes more effectively

Problem: Separating exploratory, combinatorial and transformational creativity processes and techniques in different workshops left some ideas under-developed.

Solution: Structure workshops around ideas rather than processes. Interleave techniques for combinatorial and transformational creative thinking to explore single ideas to their conclusion, marking spin-off ideas to be returned to later. Encourage participants to explore ideas depth-first until the idea is either rejected or concrete requirements emerge. Structure pending ideas using visible idea lists and frequent prioritization and re-prioritization of established ideas as the set of ideas evolves.

Structuring workshops around ideas requires more flexible use of domain experts to fulfill different creativity roles. Other experts we considered included *fashion designers* (exploratory), *DJs, cocktail bartenders, cartoonists* (combinatorial), *science writers and graphic artists* (transformational). Build up a network of experts and categorize their contributions in terms of domain knowledge to deliver and types of creativity to support. NATURE's problem domain categories (Sutcliffe & Maiden 1998) provides a faceted classification scheme of domain expertise that enables quick identification of experts.

5.4. Report back the rationale behind ideas

Problem: As idea incubation often defied linear thought, and idea generation was in small groups, ideas and their rationale were sometimes lost to the wider requirements process.

Solution: Hold frequent report-back sessions across groups to elicit rationale and communicate it to other participants. Have a scribe who is independent of the

requirements process to record idea rationale using argumentation techniques (Moran & Carroll 1996).

5.5. Allow people to let off steam

Problem: Participants are not always ready to be creative. They can bring problems, political issues and other baggage that can inhibit creative thinking, as happened in the first workshop.

Solution: Give participants one or more periods to let off steam before being creative – it is only natural that people need to vent their frustration when faced with change. This happened, somewhat by accident, in our workshops. The first workshop gave people the chance to let off steam, which helped the second one to produce more creative requirements and ideas.

5.6. Plan, plan, plan the workshops

Problem: Scheduling creative activities can be difficult, as it is hard to predict the directions that creative processes will take. However, it is essential to plan when experts will be needed to ensure their participation.

Solution: A workshop that appears to participants over-planned is less likely to encourage creativity. Instead workshops should appear flexible, fluid and responsive. Facilitators should have plans that can be invoked to handle most situations.

5.7. Find a champion for the workshops

Problem: Setting up the workshop was a challenge, as creativity workshops are not cheap to run and the benefits to be gained from having the domain experts present were not always obvious.

Solution: Find people who will champion the workshops. We attribute the CORA-2 success to managers and stakeholders who did just this. The CORA-2 program manager backed our unusual ideas, and the workshops themselves benefits from key stakeholders who embraced and supported the creative opportunities given to them.

6. Integrated Creativity Workshops into Structured Processes

Although the workshops delivered outputs that were useful to the CORA-2 project – the resulting CORA-2 specification was reviewed, accepted and is currently being used to provide a CORA-2 system prototype – we identified problems from which we drew lessons that have been applied in subsequent workshops. One overriding challenge is to integrate creativity workshops into structured requirements processes that provide inputs into the workshops and utilize outputs from them. In RESCUE we now run the creativity workshops early in the requirements process, after the system boundaries are established but before the key design concepts and use cases are specified. Inputs to each workshop are context and use case models and informal use case précis that are later modified and extended in light of workshop outcomes. Establishing first-cut system services within boundaries allows us maintain focus during the workshop and deliver more useful outputs. These outputs – requirements and design ideas – then enable the team to model system goals and write precise use

case specifications that, in turn, are used to acquire more detailed requirements using ART-SCENE scenario walkthroughs (Mavin & Maiden 2003).

Our longer-term research aim is to integrate further and embed creativity techniques into structured requirements beyond workshops. To do this we will categorize existing requirements techniques (e.g. use case analysis or functional decomposition) according to their support for different creative processes and techniques. However, current theories of creativity from cognitive and social psychology and artificial intelligence such as those cited in this paper are insufficient. We needed to interpret and apply them with care to design the 3 workshops. The software development community needs new and more applied creativity models that will provide software engineers with the right facilitation skills and guidelines for technique selection.

So how should we develop these applied creativity models? Our position is that these new models must be informed by requirements artifacts and representations, such as use case précis in text form and multi-media storyboards, which are used in structured requirements processes as important communication tools. To this end we are currently developing applied models that will associate different artifact properties (e.g. *interactive scenario*) with creative processes (*exploratory*) and techniques that these properties support (*e.g. random idea generation with what-if questions*), in the presence of assumptions about the creative activities and environment. We anticipate that such an applied model will prescribe creative activities within structured requirements processes, using existing cognitive and psychology models (e.g. Boden 1990) to describe and explain the creative processes. At a more fine-grain level it will also help creativity workshop facilitators to choose the right techniques to support and interleave creativity processes.

We hope that the reported experience and lessons guide readers to make their own requirement activities more creative. We have exploited these lessons learned both to run more creativity workshops (e.g. Pennell & Maiden 2003) and design tutorials and workshops to help others do the same.

7. Acknowledgements

We wish to thank Eurocontrol and all workshop participants.

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