Understanding and Supporting Technical Creativity

Corina Sas
Computing/Infolab21
Lancaster University
Lancaster, LA1 4YR, UK
corina@comp.lancs.ac.uk
+44 1524 510318

Alan Dix
Computing/Infolab21
Lancaster University
Lancaster, LA1 4YR, UK
alan@hcibook.com
+44 1524 510319

ABSTRACT
This paper explores the topic of exploration (sic) within the design space and discusses how this can support the development of research design. It highlights the relevance of reflecting upon the exploration of the design space and introduces a set of techniques that can be used for this.

Author Keywords
Design research, design space, idea generation, reflection in action.

INTRODUCTION

Current understanding and practice of interaction design has limitations which explain the challenges that this field encounters in order to meet the ever increasing demands of information technology.

Such challenges are primarily due to our limited understanding of what design is and how it really occurs. A large amount of work is being carried out to unfold the craftsmanship dimension of design and better articulate practitioners' knowledge in codes of best practices [8],[13],[15]. Such codes would facilitate the acquisition of practical skills in industrial settings, and more importantly, become an integral part of academic training.

Despite the efforts deployed in this direction, the academic study of design is still in its infancy. In order to elevate the study of the design from the status of art and craft to one of science, a leap from practice to theory should be made. For this, researchers should develop theories through articulation and inductive inquiry [6].

In the context of craftsmanship it is worth mentioning the distinction between procedural knowledge and declarative knowledge, that has long been acknowledged in many theories of learning and cognition [12].

Declarative knowledge is knowledge that people can report and of which they are consciously aware. Offering a descriptive representation of knowledge, declarative knowledge expresses facts, like what things are [14]. On the other hand, procedural knowledge is that knowledge that people cannot verbalize. They form part of a mental model which enables the execution of some tasks because of the technical skills capturing the "knowing-how" [2]. Because of the lack of awareness characterizing it, procedural knowledge is usually taken for granted [1].

The successful development of design field requires both declarative knowledge and procedural knowledge. Part of the challenge of the theoretical accounts for design is to unfold the procedural knowledge embedded in tacit practice and lift this to the level of declarative knowledge (see also [6]).

EXPLORING DESIGN SPACE

This paper reflects on the efficient exploration of the design space and puts forward the following research questions:

- What constitute an exploration?
- Is the exploration of some specific (possibly odd) places within the design space more useful as opposed to random exploration?
- Which are the techniques for identifying such specific odd places?

Traditional design often proceeds by generating ideas which are assessed so that the idea that best meets the design constraints is further *incrementally* improved and ultimately implemented.

This approach of many small steps limits the exploration of the design space and it is also problematic within truly novel domains. A challenge for design is to generate initial ideas which are better, more novel or more provocative to our understanding. Ways of generating ideas to support a particular design problem include:

- Generative approaches are applied when the thinker has access to a set of examples that can address the problem but wishes to move away from them and discover something new and better. It involves the identification of all those examples and an analysis of how each of them succeeds or fails to address the design constraints. This analysis will support the elaboration of a new, hybrid idea able to account for more than the initial ideas.
- Transformative approaches are applied when there are no examples to address a design problem. In this case, the person takes a single (alien) example from a different (although often related) category or problem domain and identify a series of alterations that bring the alien ideas into the desired category [5].

Idea generation and evaluation is a process which involves two planes: the abstract and the concrete. The abstract plane involves reflection and understanding, while the concrete plane involves artifacts, examples or ideas (Fig 1).

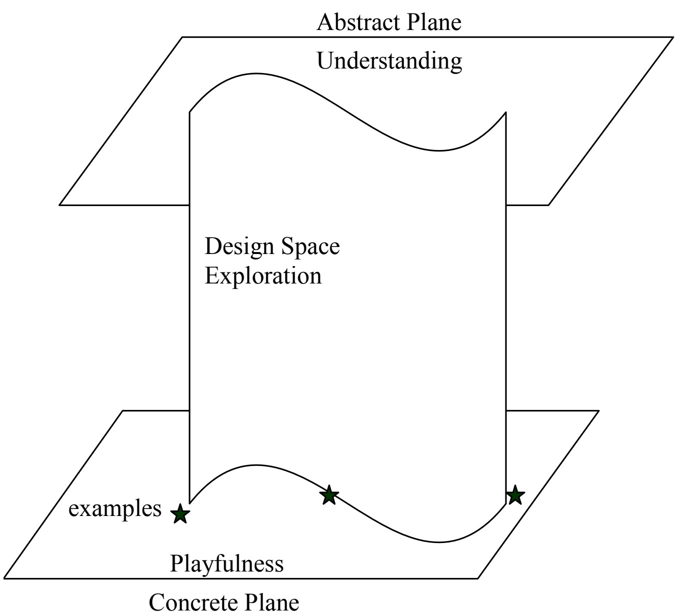

Figure 1: The exploration of design space allows fluid movements between the concrete plane involving examples, i.e. artifacts or ideas, and the abstract plane involving reflection on examples and understanding of their abstract dimensions.

A good exploration of the design space will allow fluid movements between these two planes, where examples are used to gain a better understanding which in turn is used to generate or refine concrete ideas. The points in the design space do not necessarily have an intrinsic value, (e.g. labeled as good or bad) but they become relevant for enabling the understanding of the significant dimensions within the design space.

Such fluid movements between these two planes can occur through acting in the physical plane and reflecting upon it in order to reach understanding and the associated abstractions required in the abstract plane. Constructivism and reflection in action are two theoretical frameworks that account for this.

Constructivism is an approach to learning which considers that people construct their own understanding through experiencing things and reflecting on their experience [10]. Through this reflection component, constructivism is related to “reflection in action” approach [11], but it does not necessarily require action. Building on constructivism, experiential learning is an approach which considers fours stages of learning: concrete experience, reflection, abstract conceptualization and active experimentation [9].

The benefits of bridging the two planes and the associated relevance of this topic are outlines below.

TOPIC RELEVANCE

The efficient exploration of the design space will lead to the identification of new points within it. The evaluation of these points will enable the understanding of the relevant features underlying the design space. The outcome of the evaluation process does not refer to assigning values to these points but to identifying how much such points reveal about the design space and furthermore support its understanding.

The exploration of the design space could support both generalization and prediction for developing designs within the same class of requirements. This relates to reproducing the design process and anticipating its outcome. The fluid movements between the concrete and abstract planes facilitate the development of descriptive knowledge, e.g. why things are like they are; predictive knowledge, e.g. what is the outcome for a given condition; and more importantly, synthetic knowledge, e.g. what are the conditions for a desirable outcome.

TECHNIQUES FOR EXPLORING THE DESIGN SPACE

This section describes three techniques aiming to support the efficient exploration of the design space. The first technique is Bad Ideas previously introduced by Dix et al. [4], and further refined within this paper. The other two techniques are critical transitions and multiple classification.

Bad ideas

This technique capitalizes on often accidental way in which bad ideas become beneficial detours enlarging the pool of good ideas (Fig 2) aiming to solve a particular problem [4].

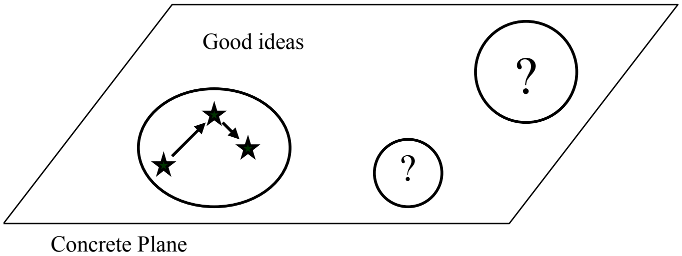

Figure 2: The exploration of Good Ideas allows an incremental exploration of the concrete plane, and thus a local exploration which leaves unexplored large areas of this plane.

Instead of these being accidents, participants are encouraged to deliberately create bad ideas which are consequently systematically analyzed. Bad ideas encourage both divergent thinking and a more structured analysis of the problem (Fig 3). Through its inner features, e.g. impossible, impractical, or just absurd, a bad idea pulls the person to a new, unpredictable place within the design space.

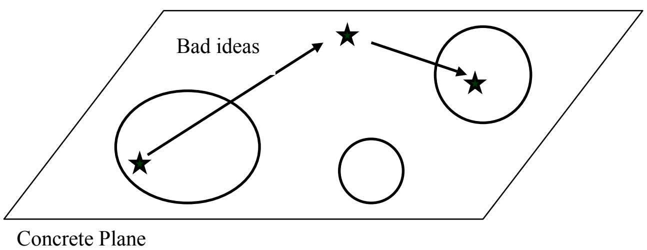

Figure 3: The exploration of Bad Ideas in the concrete plane particularly facilitates movement to far away areas, which thus overcome the drawbacks of the limited exploration that Good Ideas entail.

The exploration of both the bad and the good involves four questions: (i) what is good/bad about this idea, (ii) why is this a good/bad thing, (iii) are there any other things that share this feature but is not good/bad, (iv) if so what is the difference (Fig4).

The benefits of this technique reside in developing good ideas from the bad ones, with the support of four prompts: (i) keeping the good aspects of the good ideas, (ii) exploring the good aspects of the bad idea, (iii) changing the context where the bad idea can become a good one, and (iv) role play for engaging in the exploration of bad ideas. Because bad ideas usually violate the design goals or constraints, this process enables the articulation of dimensions and properties of the design space. Besides supporting critical thinking, bad ideas enable the exploration and even more important, the understanding of the design space, by reducing also the emotional attachment that people usually develop towards their good ideas.

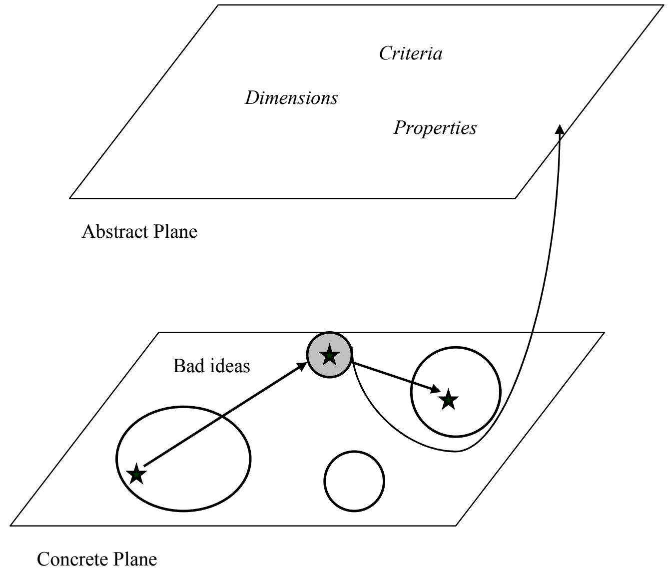

Figure 4: The exploration of Bad Ideas on the concrete plane impacts on discovering important aspects of the design space through reflection taking place in the abstract plane.

Critical transitions

This method consists in identifying key points within the concrete place, e.g. prototypical examples for various categories, and then identifying intermediate examples together with the categories they belong to.

In order to construct a boundary case, one can use the following three steps: (i) identifying two examples: one belonging to the category, i.e. example A, and one not in the category, i.e. example B; (ii) making path of small changes from A to B, and (iii) identifying the point where the path crosses the category boundary (Fig5).

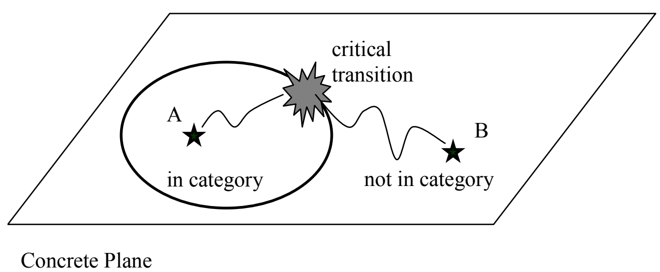

Figure 5: Constructing boundary case in the concrete plane, by identifying the critical transition point, where the path between the two category examples crosses the category boundary.

This allows the identification of those points of transition where a small change shifts the example from one category to another. By doing this one can discover the attribute that changed and thus became critical for a given category [3].

However, the identification of examples is not a trivial task, although for this, one can draw upon prior experience and previous related concepts. In this way, the process of generating examples is originated in the past. Another approach to generating examples originates in the present experience (as opposed to past one) which is centered on the need for a new concept for which a direct match is difficult to find in the previous experience.

In this case, the process of example generation consists in (i) identifying arbitrary concrete examples, (ii) morphing them to a new concept, and (iii) identifying similar surface characteristics which can link the new concept with some examples encountered in previous experience. While finding examples is itself hard, small changes in a direction are often easier than just 'thinking up" and example in a category.

Specifically, in order to understand a particular concept/category, one can look for example A in that category and try to slowly morph the example A into an example B not in the category. As one creates the series of example there comes a point when the example stops being 'in' the category. So if the series of examples is A, A1, A2, A3, A4, A5, B and A, A1, A2, and A3 are in the category and A4, A5 and B are not in the category, then one will chose the two either side of the transition , A3 and A4 and ask "what is the difference?" If this is still difficult to address, one will look for smaller differences to generate additional examples between A and A4. As ones does this, focusing closer and closer to the critical transition, eventually an insight may occur "aha that is why ... " which will help the articulation of those qualities that have changed as one progresses through the incremental changes.

The criteria or dimensions that one articulates by examining these critical transitions are not necessarily those that 'define' the category of interest, but those that are clearly germane to it. By studying several such critical transitions of different kinds one begins to build up a vocabulary of issues, dimensions and criteria that enable the articulation of the central qualities of the category as well as its boundaries. Not at least, the aim of this is NOT to produce a clear water-tight definition of the category, but instead by analysing the edges of the category to develop and understanding of its heart.

On reflection, the link between the Bad Ideas and Critical Transitions relates to the fact that the bad idea is outside the category of 'good designs', while the process of "why bad/good" inquiry is also about creating vocabulary for specifically looking at the single 'bad' example and using that as a foil to articulate its differences from the general 'good' category. The "what shares this bad quality but is good?" (and the opposite for good points) is effectively creating a 'close' example inside the category 'good ideas', that is deliberately creating a critical transition from bad to good.

Multiple classification

Another technique to explore the design space is multiple classification which involves previously identified criteria/dimensions which will be used to analyse the design space. Often people look for taxonomic classifications which look like the one below:

- A
  - A1
  - A2
    - A2.1
    - A2.2
  - A3
- B
  - B1
  - B2

These classifications are useful but only to inform about similarities near the leaves. For example let’s consider the taxonomy of things consisting of circles and squares of two different colours:

- things
  - circles
    - red circles
    - yellow circles
  - squares
    - red squares
    - yellow squares

It is easy to see that red circles and yellow circles are similar as they are 'close', but the similarity between red circles and red squares is obscured by this representation.

In contrast, a representation in the form of a cross tab (Table 1) makes it easier to see multiple kinds of relationships. This representation captures the concept of multiple classification because each individual example is described along several dimensions.

	circle	square
red		
yellow		

Table 1: Cross tab representation of a taxonomy captures multiple classifications.

Following from here, if one is interested in yellow squares and understands the concepts of 'colour' and 'shape' as dimensions, then it is obvious that literatures of red squares and yellow circles are not the most relevant as they only differ in one characteristic.

In contrast, the cross tab representation enables gap analysis: if one finds examples of systems, literature, etc. and populates the cross tab then (s)he can also see the gaps which remain unfilled. Reflection on these gaps is enabled through three types of prompts: (i) a gap might generate hypothesis, i.e. "is this and impossible category", (ii) a gap can identify and steer a new a research agenda, i.e. "lets look for things here", and (iii) a gap can prompt ideas, i.e. "ah yes you could have an X in this gap" where X is a new idea.

Gap analysis can lead to the identification of patterns to the gaps that suggest deep (similarity) relationships, i.e. maybe all yellow things are also large. Not at least, gap analysis can be used to synthesise new solutions. For example, let's imagine a target problem area, say yellow squares, for which one has no concrete examples. In this case, the neighbouring cells, which represent things that differ in one attribute only, are likely to be useful source of inspiration.

CONCLUSIONS

This paper introduces the topic of design space exploration together with three techniques for addressing it. Techniques such as Bad Ideas, Critical Transitions and Multiple Classification were described and their benefits for the exploration of the design space further discussed. Such techniques have been identified through reflection on interaction design practice and several examples were provided to support their presentation.

Future work is needed to identify ways to evaluate the distinct impact of each of these techniques on the exploration of the design space, and based on this to elaborate guidelines for selecting the appropriate technique at particular moments in the design process.

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