iEMSs 2008: International Congress on Environmental Modelling and Software
Integrating Sciences and Information Technology for Environmental Assessment and Decision Making
4th Biennial Meeting of iEMSs, http://www.iemss.org/iemss2008/index.php?n=Main.Proceedings
M. Sànchez-Marrè, J. Béjar, J. Comas, A. Rizzoli and G. Guariso (Eds.)
International Environmental Modelling and Software Society (iEMSs), 2008

On the Role of Reflection and Representation in Environmental Decision Support Systems

Timothy Maciag[a] and Daryl H. Hepting[a]

[a] *Department of Computer Science, University of Regina, 3737 Wascana Parkway, Regina, Saskatchewan, Canada, S4S 0A2 {maciagt, dhh}@cs.uregina.ca*

Abstract: Donald Norman describes how reflection enables us to critically analyse and review details, compare and contrast situational outcomes, and aid in our general decision-making abilities. Furthermore, he explains how through reflection, we increase our awareness - become smarter - which inevitably enables us to conduct more satisfying decision-making analyses. In a day and age where information is abundant, the activity of reflection may prove more difficult. This is particularly the case for evaluating alternatives for health and environmentally preferable product selection. Key in supporting consumers in such regard is the design of the user interface, one where the interactions provide satisfying user experiences through support for reflective activities supplemented by high quality representations. This paper will discuss the importance of reflection and representation in such regard by describing a framework for system design. A detailed description of the framework is provided along with a discussion describing qualitative results from a recent usability evaluation. Future work is also provided.

Keywords: Environmental decision support systems; Decision-Making analyses, Human-Computer Interaction; User-Centred interface design.

1. INTRODUCTION

Reflection is a mental activity we commonly apply in many of our *higher-level* (*non-experiential*) decision-making analyses [Norman, 1993]. As such, reflection could be considered a catalyst in facilitating our decision-making tasks as it provides the necessary cognitive activity which enables us to comparatively analyse criteria and concepts within a problem domain while effectively enabling us to conduct compensatory and non-compensatory decision-making analyses and evaluation(s) [Hoyrup, 2004; Blandford, 1991]. Reflection, and by extension – *reflective activity* [Courbasson, 2006], stimulates our decision-making processes, thereby enabling us to arrive at solutions based on our own experiences and understanding of the decision task [Hoyrup, 2004].

However, reflective activities can prove to be difficult given our own cognitive limitations [Norman, 1993]. Too much reflection and nothing would be accomplished whereas purely experiential activities may lead to poor decision solutions. Furthermore, left to our own devices, our ability to truly reflect and act upon a decision solution may be limited – as Norman [1993] and Fischer [2005] state: "*The power of the unaided individual mind is highly overrated.*" From this statement comes the realization that effective and satisfying decision-making may require the use of external decision aids. These aids could include low-level tools such as a piece of paper and a pencil but may also include higher-level tools such as those in the form of computer-aided support tools (decision support systems (DSS)). These higher-level tools may be preferred as they have potential to more effectively provide a more seamless interaction between the decision-maker and the data being analysed.

1.1 Usability in Decision Support Systems

When designing DSSs, a critical requirement in the design process is to define how best to develop an effective framework for user interaction. Norman [1993] suggests that we can achieve a high degree user satisfaction through the *power of representation.* Here, representation could refer to many aspects of design – including the user interface display, how system objects are represented on the interface, and the interface functionality, among others. The power of high quality representations cannot be understated. Consider the commonly misinterpreted proverb: "*A picture is worth a thousand words,*[1]" or its satirised version given by McCarthy "*1001 words is worth more than a picture*.[2]" – here we are provided with a deeper insight into what Norman is suggesting. In either case, regardless of their intended meanings, it becomes more clear that a representation in any form has the potential to greatly assist our decision-making abilities. Higher quality representations may ensure that decision-makers have more satisfying reflective experiences as they stimulate reflective thought – evoking a deeper exploration, which may empower the decision-maker to achieve more satisfying decision solutions [Norman, 2004]. However, designing quality representations is not a definite process – as what has meaning to some decision-makers may not have meaning to others. This task becomes even more difficult depending on the intended use of the DSS. For example, consider consumer-oriented DSSs – here, there may exist a variety of decision-maker – some with expert experience but also some who have limited understanding of the decision criteria. In this instance, more care is needed when designing the system representations.

Norman [1993] attempts to aid in this regard by describing what he believes constitutes a quality representation – being one that captures the critical aspects and decision criteria as it is viewed in the *represented world* (the "real-world") and correlating it with a depiction or illustration of the criteria as it would appear in a *representing world* (an abstraction of the "real-world" – e.g. a visual metaphor [Norman, 1988]). Here, the representation would only depict the necessary aspects of the represented world, while omitting all non-crucial aspects of its understanding. As described by Rosson and Carroll [2002], when designing such representations, it may useful to utilize the concepts of *realism* (realistic depictions) and *refinement* (more abstract depictions), as illustrated in Figure 1, which depicts two illustrations of the concept of recycling.

Rosson and Carroll [2002] indicate, in previous user studies, people have had high success in relating to realistic imagery such as that depicted on left-hand side in Figure 1. However, they add that in similar studies, people have also related well to refined imagery,

Figure 1. Two separate illustrations depicting the concept of recycling. The depiction on the left[3] illustrates the represented world (realistic) whereas the one on the right illustrates the representing world (refined)

---

1 http://www2.cs.uregina.ca/~hepting/research/web/words/history.html (Accessed March 2008)

2 http://www-formal.stanford.edu/jmc/sayings.html (Accessed March 2008)

3 Image from: http://www.uoregon.edu/~recycle/housing_kitchens_text.htm (Accessed March 2008)

such as that depicted in right-hand side of Figure 1. In either case, they conclude that designers need to consider the *process of recognition* – meaning that in some instances, it may be that people take less time to cognitively process refined representations – as realistic imagery tends to be more complex in nature. As illustrated in Figure 1, it may be that more people will immediately understand the intended meaning of the refined image of recycling as opposed to the realistic illustration as it is unclear of the true activity being performed – *is she recycling? - or putting things in the trash? – or picking certain items out from each bin?*

We hypothesize that the role of reflection and representation is paramount in the design of any DSS. In this sense, successful frameworks for DSS design would enable decision-makers to effectively conduct reflective activities founded by their interactions with high-quality representations. Specifically in the research described in this paper, we are interested in studying these concepts in relation to environmental decision support systems (EDSSs). In the case of EDSSs, reflection and representation may play an even more critical aspect of system design given the unique nature of such systems, as will be discussed in the proceeding section.

1.2 Environmental Decision Support Systems

Swayne et al. [2000] define an EDSS as "*an information system containing at least one component whose purpose is to support human decision-making about an environmental issue.*" For the purposes of this paper, we focus on particular EDSSs for environmentally preferable purchasing. This type of EDSS is unique in that many of its potential users may not have specialized training in the decision domain (e.g. expertise levels may range from uniformed-less experienced user to the informed-expert). As such, information and the way it is represented is a critical factor in the underlying success of these kinds of EDSSs. In this regard, the usability of such systems is still an important determinant of their success [Frysinger, 2003], but the design's success may also be closely correlated with the decision-maker's perception and comprehension of the decision criteria and their ability to reflect and use the support tool(s) to arrive at satisfying decision solutions.

Given the abundance and complex nature of information relating to environmental and health related issues, the task of designing quality representations is even more arduous [Frysinger, 2005]. We hypothesize that EDSSs should enable users to: decipher quality information from the quantity, comprehend system representations, reflect upon obtained results, and formulate satisfying decision solutions [Hepting and Maciag, 2005]. We illustrate this hypothesis by describing a new framework for design and evaluating it with a previously developed EDSS designed by the United States Environmental Protection Agency (US-EPA). A usability evaluation was conducted comparing each EDSS framework and qualitative (and quantitative) results relating to user interaction were collected. For the purposes of this paper, we emphasise the qualitative results obtained from the evaluation as they may provide a deeper insight into what the user truly thinks about the system.

2. FRAMEWORKS FOR EVALUATION

Recently, the US-EPA developed an online EDSS for environmentally preferable purchasing of cleaning products using a database of 29 cleaning products distinguished between eight environmental and health related features – including:

- skin irritation, food chain exposure, air pollution potential (volatile organic compound percentage – VOC %), fragrance, dye, recyclable paper packaging, concentrated packaging, minimizing exposure to concentrated packaging

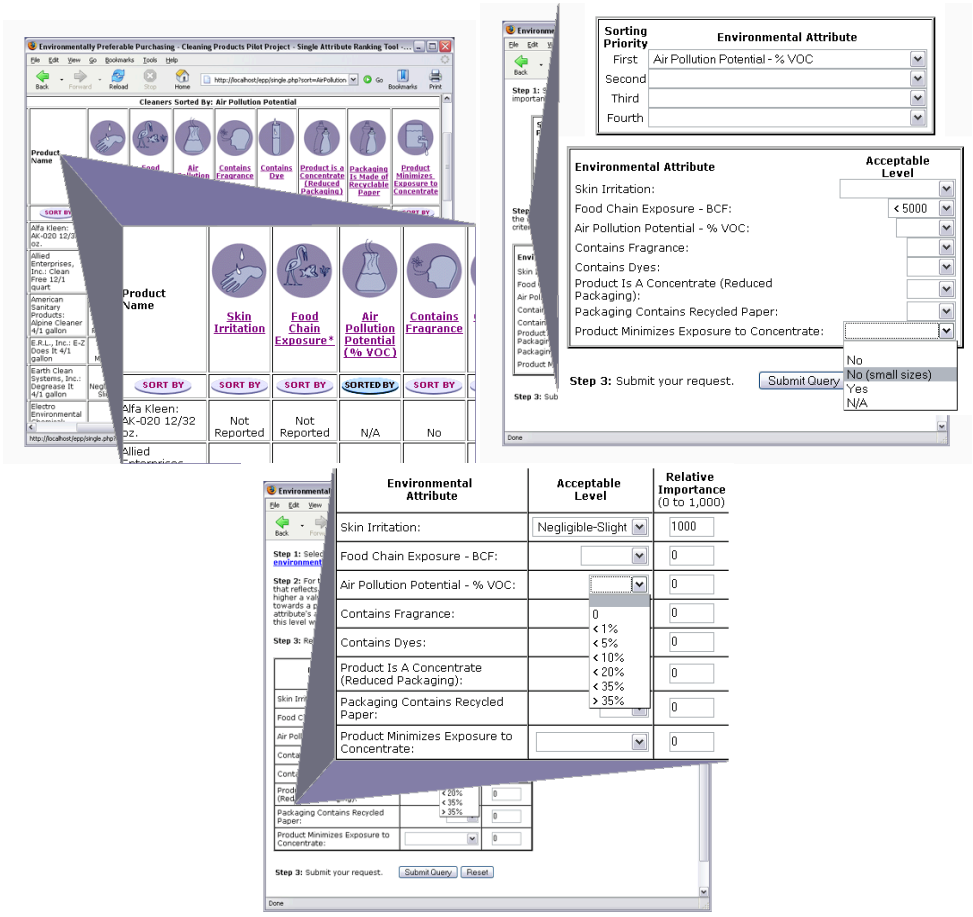

Figure 2. Single-feature ranking tool (upper-left), multiple-feature ranking tool (upper-right), and the weighted-feature ranking tool (bottom-centre). Each tool has a portion of its interface magnified for illustration purposes.

The US-EPA EDSS provided three different interface representations that enabled users to conduct reflective analyses. These were comprised of a single-feature ranking tool – enabling users to sort products by a single feature, a multiple-feature ranking tool – enabling users to sort products using up to four features with defined levels of priority, and a weighted-feature ranking tool – enabling users to sort products using up to all eight features with weighted importance values ranging from 0-unimportant, to 1000-most important. All three tools are illustrated in Figure 2. In all three instances, search results were presented to users in a tabular display, similar to that depicted in the illustration of the single-feature ranking tool in Figure 2.

In setting up our examination, we incorporated the product data and feature representations from the US-EPA EDSS into our own framework for design, which was based on a system originally developed by Hepting [2002] called *cogito*. *Cogito* differs from the US-EPA EDSS in terms of its primary interface representation as well as the way system objects are represented and displayed to the user (core system functionality also differs but that is beyond the scope of this paper). Instead of representing products in a tabular display, *cogito* uses a cell-type representation, comprised of up to eight cells per *cogito* page (up to how many pages are required). The system objects were represented in two separate ways, one being a textual (html-based) representation whereas the other, a graphical (nightingale rose-based) representation. Users were able to sort products by selecting which features and feature values (using in or all possible combinations) they were interested in reflecting upon. The *cogito*-based interface representations are presented in Figure 3.

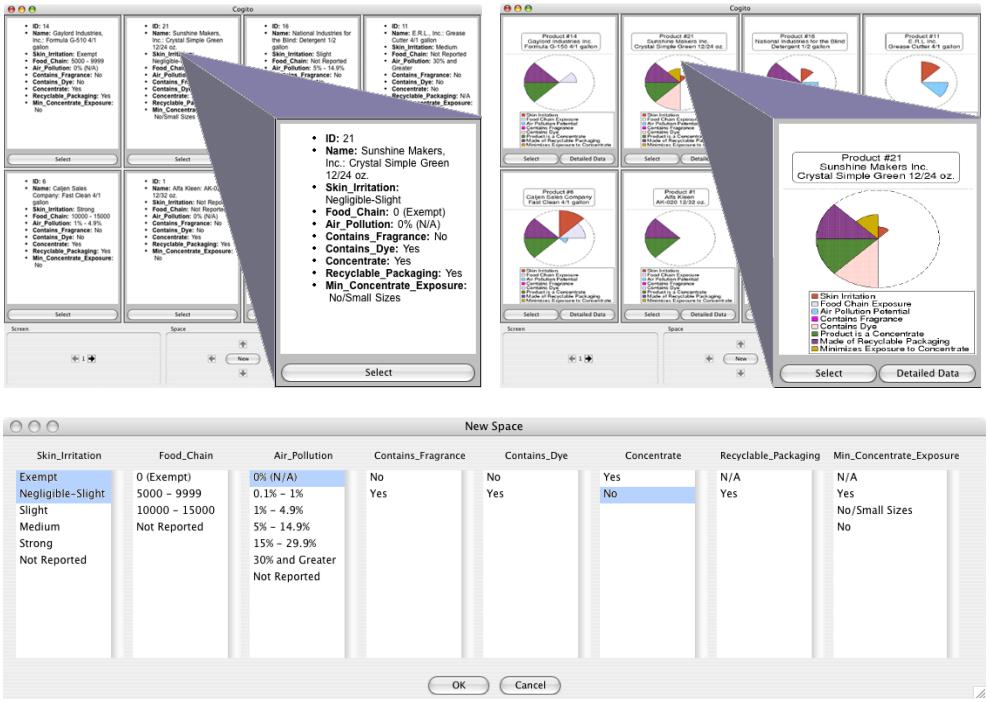

Figure 3. Cogito-based frameworks – Textual-based representation (upper-left), graphical-based representation (upper-right), and the search/query mechanism (bottom-centre). Both the textual and graphical representations have a cell magnified for illustration purposes.

3. EVALUATION

We used the US-EPA EDSS to conduct an analytical comparison with our *cogito*-based framework. We acknowledge that both EDSSs may enable some degree of reflective activity and that both provide quality representations of system objects. In this regard, the US-EPA EDSS provided three separate tools that enable reflection through a tabular representation. The *cogito*-based tools are similar to each other, but differ in terms of how the system objects are represented – textual versus graphical representations. Although it may be that all of these different representations provide reflection, for our examination, we were most interested in determining the degree at which each type of representation was successful in aiding the users. As such, it was subjective opinions of user satisfaction that we were most interested in acquiring and analysing.

For our evaluation, we recruited 28 participants from the University of Regina Computer Science Participant Pool [Hepting, 2006]. The participants were asked to perform a variety of reflective activities on the EDSSs and afterwards asked to relate their experiences by completing a questionnaire [Maciag, 2007]. In trying to obtain useful information from our participants, we asked questions relating to how they perceived the quality of their overall reflective experience – such as whether the tabular representation of the US-EPA EDSSs provided an adequate basis for reflection or whether the textual or graphical *cogito*-based representations provided a more preferred reflective environment.

Furthermore, we wanted to evaluate the participants' comprehension of certain criteria within the problem domain. We wanted to examine the correlation between participant responses and their intended perceptions. This was an attempt to rate the quality of the chosen features used to represent the cleaning products. Expert users may be able to satisfactorily define the given criteria with relative ease. However, we were interested if the same was possible for those who may be less experienced – for as previously mentioned, we hypothesize that this type of EDSS should provide support for both experts and non-experts alike. As such, we elicited the participants' interpretations of what we

considered were the more complex, or potentially problematic features representing the cleaning products. These included: *food chain exposure (fce), volatile organic compound (VOC)* - in relation to *air pollution potential, concentrated packaging (con), and minimizes exposure to concentrate (exp)*. We also made note of any open-ended comments given by the participants. Results of this analysis proved quite interesting.

4. RESULTS AND DISCUSSION

When we asked participants to state their degree of agreement in terms of how the objects were represented by each EDSS and whether the representation enabled reflective activities, results indicated a slight preference for the graphical-based *cogito* EDSS. When asked whether the tabular representation provided by the US-EPA EDSS was conducive to reflective activities, 71% agreed (25% strongly agreed). When asked whether the textual representations provided by the *cogito*-based EDSS were conducive to reflective activities, only 64% of the participants agreed (14% strongly agreed). Finally, when asked whether the graphical representations provided by the *cogito*-based EDSS were conducive to reflective activities, 75% agreed (39% strongly agreed).

Looking back on the data collected we noted that many participants had a high exposure to tabular data on a monthly basis – 71%, with over half of the participants (57%) having weekly exposure. This could be why a higher percentage of participants felt that the tabular representations provided such an effective representation for reflective thought. In terms of the results obtained for the textual-based and graphical-based *cogito* EDSSs, one of the factors that may have contributed to the lower percentage of participants who thought the textual-*cogito* was less conducive to reflective activities may be that the textual representations provided a more realistic depiction of the cleaning products. For example, when shopping in a local market, a consumer can easily pick up a product and read its ingredient label. Here, there is only a slight difference between the represented world and the representing world – thus, the need for, and use of an external decision aid may be perceived as redundant. The tabular representations provided by the US-EPA tools may also evoke a similar response in such regard. However, given the participants' previous exposure to tabular data – results may have been skewed in its favour. Opinions relating to the graphical-based *cogito* EDSS provided insight into the power of refined illustrations. This was further indicated in open-ended comments given by the participants [Maciag, 2007] – that the graphical imagery was preferred, as upon first glance, you obtained an instant "feel" (stimuli) for the product. Many participants also commented on how the *cogito* EDSS provided a more conducive environment to conduct reflective activities given its cell-type user interface representation, as opposed to having to scan through the complex tabular display provided by the US-EPA.

When observing the results of our examination of user comprehension, results were interesting. One of the questions we asked the participants was whether they felt that the eight features representing the cleaning products (Section 2) were understandable and helpful in their reflective activities. 96% agreed (36% strongly agreed) that they were. However, when asked to define some of the *more complex* features, results contradicted the previous indicators as there was a rather large disconnect between how well the participants' defined the features and whether they thought they were understandable and helpful. The average participant score for each definition was below 50%, with only *fce*: 25%, *voc*: 29%, *con*: 14%, and *exp*: 36% of participants who correctly defined the respective definitions – thus, indicating the majority lacked a true understanding of the criteria. This provided a realization of the need to re-evaluate certain product feature representations. However, these results may indicate a larger issue, being that the participants almost unanimously stated their agreement that the features were understandable and helpful, yet were unable to successfully indicate their comprehension of them. *Could it be that the participant's simply did not consider these four features as being important in their reflective activities?*, or, *could it be that since these four representations were provided by the EDSS by default, that they were assumed to be important?* Many questions arise from these results. However, more research is required in this regard.

5. CONCLUSION

This paper examined the role of reflection and representation in EDSSs. Almost any EDSS will enable its users to conduct reflective activities. However, it is the degree to which reflective activities can be effectively, and satisfactorily conducted that denote the success of the EDSS. Through our examination, we illustrated that for an EDSS to be effective in such a manner the support framework upon which the system is built must incorporate high quality system representations – ranging from the user interface display to how system objects are modelled and represented. We noted that designing quality representations is an ongoing practice – as what has meaning to some users may not have meaning to others. In this regard, from our examination it was shown that some users might prefer more refined representations, while others may prefer more realistic ones. Deciding which representation to model the system by may be unique to the decision domain. We hypothesize that designers need to continually examine the needs of their users' in order to ensure they can satisfactorily conduct their reflective activities and obtain satisfying decision solutions. Many questions still exist and there are many opportunities for future analysis. Future work will include further analyses on the role of reflection and representation and deeper analysis in understanding how to best to design EDSS to ensure user satisfaction in such regard.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Centre for Sustainable Communities at the University of Regina and the Natural Sciences and Engineering Research Council (NSERC) of Canada

REFERENCES

Blandford, A., Computer Support for the Development of Decision-Making Skills, *British Journal of Educational Technology,* 22(1), 48-59, 1991.

Courbasson C.M., Reflective Activity and its Measurement, *International Journal of Mental Health Addiction,* 4, 133-149, 2006.

Fischer, G., Social Creativity: Making All Voices Heard, In Proc. HCI International Conference, 2005.

Frysinger, S.P., Human Factors of Environmental Decision Support Systems, In Proc. International Symposium on Environmental Software Systems (ISESS), 2003.

Frysinger, S.P., Cognitive Considerations in Environmental Decision Support, In Proc. International Symposium on Environmental Software Systems (ISESS), 2005.

Hepting, D.H., Towards a Visual Interface for Information Visualization, In Proc. Information Visualization, 295-302, 2002.

Hepting, D.H. and Maciag, T., Consumer Decision Support for Product Selection, In Proc. International Symposium on Environmental Software Systems (ISESS), 2005.

Hepting, D.H., Ethics ad Usability Testing in Computer Science Education, *ACM Special Interest Group on Computer Science Education*, 36(2), 76-80, 2006.

Hoyrup, S., Reflection as a Core Process in Organisational Learning, *Journal of Workplace Learning*, 16(8), 442-454, 2004.

Maciag, T., Supporting Sustainable Decision-Making: Evaluation of Previous Support Tools with New Designs, VDM Verlag Dr. Muller, 2007.

Norman, D., The Design of Everyday Things, Basic Books, 1988.

Norman, D., Things That Make Us Smart, Basic Books, 1993.

Norman, D., Emotional Design, Basic Books, 2004.

Rosson, M.B. and Carroll, J.M., Usability Engineering: Scenario-Based Development of Human-Computer Interaction. Academic Press, 2002

Swayne, D.A., Denzer, R., Lilburne, L., Purvis, M., Qwinn, N.W.T., and Storey, A., Environmental Decision Support Systems: Exactly What Are They? *Environmental Software Systems*, 259-268, 2000.