Contributing to and Using a Shared Design Memory: Effects on Learning Analysis and Design Skills

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Abstract

Contributing to and Using a Shared Design Memory:
Effects on Learning Analysis and Design Skills

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A shared design memory emerging from the contributions of novice designers affords, theoretically, unique opportunities to support individual and organizational learning. StoryNet, is a shared design memory implemented, using a groupware technology, to support learning information systems analysis and design. It allows the retrieval of precedent design cases for re-use and adaptation, and the examination of the peer reviews and comments that have been attached to such design cases. Its architecture is finalized to operate in synergy with a specific methodological approach to design, to offset some of the cognitive biases and difficulties that novice analysts and designers have to face. Starting from the premise that the effects of shared memory on learning have to be understood within a framework that takes into account the social and cultural nature of the "distributed" system that becomes realized, this exploratory, qualitatively grounded study addresses the relationships among the learners' individual characteristics, the use of design precedents, the perceived difficulty of the design activity, the attitudes towards StoryNet, and the quality of the outcome design artifacts that are generated. Organizational learning is reflected in the emergent qualities of the design produced by different generations of design teams, indicating what design weaknesses typical of novices are being offset, and what good design practices and features are diffused and gradually incorporated as new quality standards.

The findings of the study point out some differences in using the precedents and the information provided in StoryNet that arise from differences in the learner's initial design experience, and some limits of the shared memory in representing design knowledge in context.

The analysis of three generations of designs suggests that the shared memory was instrumental to attaining a new overall design quality, sustained by an increased emphasis placed on structuring and communicating according to visual, temporal and hypertextual modalities, and on explaining key design steps. A socio-cognitive account of the dynamics of individual learning and of the process of increasing the quality standards of the design for the community, through socially regulated, adaptive evolution mediated by the shared memory, is provided.

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Chapter 1

Introduction

Modern theories of knowledge and learning point out how knowledge is distributed in networks of social actors, resources and artifacts (e.g., Engeström, 1990; Lave & Wenger, 1991; Salomon, 1993; Pea, 1993) and how cognition is fundamentally a situated and cultural process (Suchman, 1988; Lave, 1988, Hutchins, 1996). Schools of thought that view cognition as distributed, either among social actors or among social actors and the environment, propose an interactionist model of knowledge construction, in which interaction and collaboration are constitutive to learning, rather than simply instrumental to it. In these views, individual learning is very much a process of enculturation, of being introduced to the modes of discourse of a particular community, of participating in a social process of making sense and negotiating understandings, mostly through narrative construction (Bruner, 1990; Brown & Duguid, 1991).

Some of the above mentioned theoretical underpinnings are reflected, with varying degrees, in recent approaches to the design of computer-based learning environments, broadly falling under the camp of the emerging paradigm of Computer-Supported-Collaborative-Learning (CSCL) (e.g., Silverman, 1995; Koschmann, 1996). These environments share an emphasis on the "authenticity" of the learners activities, and they aim to encourage productive forms of collaboration, by creating contexts in which collaborative interaction is motivated, for example for complex problem-solving (Cognition and Technology Group at University of Vanderbilt, 1990), or for building a joint understanding of some phenomenon (Roschelle & Clancey, 1992). Besides making more accessible the resources instrumental to the activities or "practices" of a team, or of a community of learners, some of these learning environments tend to structure the computer-mediated interactions among the participants in the learning experience in such a way as to foster the mode of discourse or reasoning (e.g., scientific, technical, design, literary) that is, supposedly, more adequate to the task. For example, the learners' electronic notes and discussion threads can be labeled according to types such as "the problem", "my theory", "evidence", "I need to understand" and so on (Scardamalia & Bereiter, 1993; Guzdial et al., 1996), and in principle, this should also help retrieval for later use by other groups or members of the community.

The educational affordances more often claimed with the deployment of computer-supported collaborative systems foster individual learning through reflection, communication, articulation of ideas, motivation, or enhancing metacognition, and the design of such systems tends to be grounded on principles of learning mostly stemming from the cognitive tradition (Koschmann, Kelson, Feltovich, & Barrows, 1996). This is not surprising, because, although in the background of these studies the social nature of learning is certainly acknowledged, there is not necessarily agreement on the consequences, theoretical and methodological, of taking seriously the idea that, in some sense, cognition can be "socially shared" or "distributed". As it is pointed out by Cole (1996), much of what is meant by social in the notion of socially shared cognition is rather cultural, and failing to distinguish between cultural and social contributions to the sharing of cognition leads to an "unfortunate recreation of the dualistic approach to the individual and the social" which also makes it impossible to elucidate the dynamics of developmental change. Culture, in Cole's words, can be seen as the full set of resources for constructing contexts, i.e., combinations of goals, tools shaped by the cultural past, and current circumstances, which constitute the *text* and *con-text* of behavior and the ways in which cognition can be said to be distributed in that context (emphasis in original).

Indeed, the dualism between individual and social, or individual and the environment, still hovers in many debates or statements. For example, the distinction between effects *of* technology and effects *with* technology (Salomon et al., 1991) has been the object of much discussion, in the attempt to reconceptualize a notion of knowledge transfer, i.e., the ability to apply knowledge in novel situations, compatible with a view of learning and practice in a context of social and technological resources. Yet, Kolodner and Guzdial (1996) advocate more attention towards the effects *of* technology in the individuals while assessing CSCL, although, at least, they cast some doubts on the adequacy of the methods traditionally used so far to assess individual learning and transfer, if such learning has taken place in a collaborative setting.

Two consequences of the situated and cultural nature of learning for the development of individual competencies and skills in an educational setting are that 1) such competencies have to be cultivated in a continuous process of exchange and co-determination with the social and material resources that are brought together in the learning context, and 2) that the emergent quality that such a "geography" of resources and relationships acquires affects very much the results that can be attained, both at the individual level and at the level of the overall community of learners.

Paying explicit attention to this geography and its dynamics to guide interventions for supporting learning and performance is a challenging endeavor, in many respects. It requires an understanding of how resources are used, of the cognitive and social consequences of their use, and an understanding of how the communication and collaboration flux that surrounds them to make them meaningful and useful arises.

This latter point is particularly emphasized in studies of organizational learning (Levitt & March, 1988; Huber, 1991; Giordano, 1994), i.e., the emergent phenomenon accounting for the transmissions, in spite of the turn-over of individual members, of myths, procedures and expectations, content knowledge and misconceptions, that both enable and limit the performance of the overall organization, for example by not replicating errors that have occurred in the past, or by biasing the perceptions of what is worth paying attention to. The informal social networks among the members of the organization are crucial in sustaining (or blocking) this learning and performing process, by providing the necessary pointers to the relevant expertise and resources to face novel situations, by fueling the creation of a shared culture and knowledge base anchored to practice, and by setting the standards, the expectations, and the opportunities for thinking and advancing knowledge (Brown & Duguid, 1991).

Most of the current studies of CSCL have focused on rich descriptions of how the system is being used, with much emphasis on its educational affordances; few studies have focused on the relationships between patterns of use of the system and individual conceptual progress (e.g., Oshima et al., 1996); others have explicitly focused on the process of construction of a shared concept as happening in "real time" through collaborative conversational interaction (Roschelle, 1992).

One aspect that has been largely unexplored so far is what kind of learning consequences are involved in deploying a computer-supported collaborative system focused explicitly on supporting individual and organizational learning by making the intermediate or final product of collaboration, e.g., the solution of a problem, or the argumentation towards building a shared understanding of a phenomenon, or a design artifact, available for later use by other groups or members of the learning community.

In this case, an additional function performed by the learning environments it to create electronic "organizational memories", where the "organization" can be the classroom (e.g., Bruegge & Coyne, 1994) or the virtual community of learners that enroll in the same course in different years (Giordano, 1997b). Typical computer-supported collaborative systems can be effective in a situation in which it is realistic to expect the learners to work on a common problem, or to trigger a process of collective inquiry out of personal interests or curiosity, and use it as a learning opportunity. However, there are instructional situations in which collective engagement is not feasible or particularly appropriate, for example when the learning exercise involves a small team working on a quite open-ended task (such as solving a design problem) that can be carried out in a flexible span of time, and direct cooperation among different small design teams working on different projects is not naturally established.

Still the accumulated wisdom and experience embedded in the artifacts that have been produced in similar situations is a valuable resource to which students normally resort, possibly enriching it by informal talks to peers who have undergone a similar experience. This provides a sort of cultural continuity in which the new learning experience is bred.

This study explores qualitatively the above issues focusing on the instructional leverage afforded by StoryNet, a shared electronic design memory, which is emerging from cycles of contributions of communities of learners engaged in Information Systems

(IS) analysis and design (Giordano, 1997a ; Faro & Giordano, in press). The system allows the students to retrieve precedent design cases developed by other students, possibly for reuse and adaptation to their current design problem, and to examine any peer reviews, or any other comments, that have been attached to such design cases. The focus of the research is to what extent designers are facilitated by such a system in carrying out tasks notoriously difficult for novices and in what respects the quality of their analysis and of their design artifacts is affected by using and contributing to the shared design memory. Specifically, the objects of investigation are the relationships between the architecture of the system, the kind of resources to be shared, the individual differences among the learners and the impacts on the organizational learning of the community.

This study differs from the studies that have been presented so far in the literature in the field in various respects: 1) it addresses an instructional situation in which the learners engage in a high-level and multifaceted task, involving analysis, design and prototyping skills; 2) it is concerned with the relationship among the methodological approach to analysis and design, the individual learners' level of experience and background, the integration with classroom pedagogy, and the adequacy of the architecture of the system to collect and share experiences in the form of design cases; 3) it is done in the spirit of gaining some insight into the cognition of novice designers operating under the real constraints of preparing for an exam, in a specific context of social and material resources, and to validate against it the design and deployment of systems like StoryNet; and 4) it adopts a longitudinal approach to study some of the above mentioned issues.

The study is organized as follows. Chapter 2 is devoted to characterizing the task of learning Information Systems Analysis and Design. This is done for two reasons: first, to gain an understanding of the specific novice difficulties and biases that are involved, as documented by the empirical research in the field, and thus have an initial baseline against which traditional pedagogies can be evaluated, and second, to suggest in what respects implementing a shared design memory can work in synergy with the classroom pedagogy and the methodological approach to design taught, to offset some of the documented biases and difficulties.

Chapter 3 first relates how the general architectural principles of a shared design memory have been actualized in a StoryNet, and illustrates the context and the modalities with which it has been deployed. Then it presents the research model that is used to investigate the system, taking into account its distributed, social and cultural nature. The research model is based on a cross-analysis of data originating from 1) the contents of the shared design memory, 2) individual questionnaires, used to gather information about individual characteristics of the designers, and their attitudes and ways of approaching the shared memory; and 3) the actual design artifacts produced by different generations of design teams. In particular, the research model identifies three angles of analysis for investigating the shared design memory and characterizes organizational learning as reflected in the emergent qualities of the designs produced by different generations of design teams.

Chapter 4 presents and discusses the first part of the results of the study, based on the data relative to the students who participated in StoryNet from March 1997 to the end of July 1997. This descriptive part addresses the relationships among individual characteristics, use of design precedents, perceived difficulty of the design activities, and attitudes towards StoryNet. It also addresses the issues of how StoryNet serves as a means to highlight and show design weaknesses in context, and as a means to convey additional design knowledge through statements justified and formulated to be useful also to future student readers.

Chapter 5 provides some of the methodological ground for the second part of the study, by elucidating some theoretical and pragmatic issues involved in evaluating the quality of the conceptual models and design specifications. It also presents the instrument developed to evaluate the designs produced by the students by taking into account the diversity of the themes that have been tackled, and elaborates on how the novice biases map onto different aspects of the quality of the designs.

Chapter 6 first illustrates the method used to analyze the changes in the design generations, and then presents the results of the analysis. This is done in various steps. First two generations are compared: a sample of the design precedents available for review, and the new design cases produced in the time span until July 1997. Then a third generation of designs, produced from September to November, is introduced as a further test to evaluate the quality and stability of the effects achieved with the shared memory.

Chapter 7 is devoted to an in-depth discussion of the results from Chapter 6. The results of the analysis are used to produce an account of individual learning and of the increase in the quality standards of the designs for the community as a process of socially regulated, adaptive evolution, and to explain the specific role played by the shared design memory in this evolution.

Finally, Chapter 8 concludes the study by pointing out its implications for the design and deployment of systems such as StoryNet in contexts different from the one examined and some directions for further research.

Chapter 2

Learning Information Systems Analysis and Design

This chapter aims at providing a characterization of information systems analysis and design that highlights the particular challenges involved for novices and is also fair to the social nature of the process and of its implication for education. Thus, after a brief introduction to information systems, Section 2.2 reviews the empirical literature on the cognition of novice analysts and designer, to characterize the more stable results on the biases and difficulties that novices typically encounter. Then, Section 2.3 examines critically the pedagogical approaches typically used to teach information systems analysis and design, and the computer-based environments that have been proposed as being potentially useful to support the learning process. This discussion highlights the relative strengths and weaknesses and where the opportunities for integration or synergy lie. Section 2.4 points out how the design methodology is an important vehicle to support the learning process because it can address directly some of the difficulties highlighted in Section 2.2 and briefly illustrates a design methodology that satisfies this requirement. Finally, Section 2.5 outlines some peculiar advantages entailed by supporting the learning process with a shared design memory, setting the ground for the more detailed discussion to follow in Chapter 3.

2.1 Information Systems Analysis and Design

Information Systems can be characterized as software systems which are data-intensive, transaction-oriented and with a substantial element of human-computer interaction (Loucopolous, 1993). Broadly, information systems analysis and design is concerned with modeling the data and the processes operating on such data to design systems (e.g., databases, computer networks) that support the information requirements of a business organization (Batini, Ceri, & Navathe, 1992; Cutts, 1991) Recently, the discipline has been influenced by approaches that have advocated a user-centered approach to the definition of the requirements (Jacobson et al., 1992), and also to the design of the actual interactions in the user-interface of the system (e.g., Carroll & Rosson, 1992; Carroll, 1995).

From a methodological point view, developing information systems involves gaining knowledge about the business organization, knowledge which is subsequently "transformed" into a formal representation detailing the requirements in a form suitable for design and implementation considerations (Loucopolous, 1993). Design techniques are typically cast - with the exception of rapid prototyping approaches - in a methodological framework schematized into four main phases: 1) requirements analysis; 2) conceptual design, which involves modeling and analysis of the application domain to formalize and validate the requirements; 3) logical design, which involves outlining the system's architecture in terms of cooperating functions or objects; 4) physical design, which focuses on implementation and performance considerations. This scheme does not have to be interpreted as a waterfall model, but rather as a rationalized description of the kind of problems that designers face while designing in practice.

Structured analysis and design methodologies detail the steps in which the design process is organized, provide expressive languages and diagrammatic notations, and offer guidelines to perform each step; however, they are only of limited support to the actual analysis, requirements acquisition and comprehension (Maiden & Sutcliffe, 1992) and, in general, to the ill-structured aspects of the design process.

This points out one crucial concern of information systems design education, that is, supporting the transition from "learning to apply" any IS design technique, which involves mastering specific modeling techniques for data modeling (e.g., the entity-relationship formalism), function modeling (e.g., data flows), and process and event modeling (e.g., Petri networks), to "understanding design" and developing the competencies needed to perform effectively in those activities that are not explicitly supported by the available analysis and design methodologies.

The ill-structured aspects mainly concern: 1) capturing the requirements specifications in a conceptual model of the system and 2) the transition from the conceptual model to the logical architecture of the system to be implemented. The first activity requires strong analytical skills and is also affected by familiarity with the application domain, which helps develop a sense of relevance in identifying data and key processes in the organization (Faro & Giordano, 1996). The second activity tends to be ill-structured because it involves mappings among models which do not have the same expressive power (Bouzeghoub, 1993).

Another concern is to induce and consolidate in the learners the diagnostic and metacognitive skills involved in validating the conceptual model, with respect to its semantic and its dynamic aspects. Recently, aspects related to team collaboration and communication skills have been acknowledged as important (Catledge & Potts, 1996) and therefore have been considered explicitly in the design of the learning experience (Macaulay & Mylopolous, 1995).

Provided this general scenario, suggestions regarding how to support the teaching and learning needs of introductory information systems (IS) analysis and design courses must take into account a characterization of the kind of reasoning that novices tend to engage in, and of the biases and difficulties that are involved.

2.2 Biases and difficulties for novice analysts and designers

The empirical studies of the cognition of novice analysts and designers have mainly focused on the relative merits and effects on performance of different formalisms or modeling tools (Jarvenpaa & Machesky, 1989; Batra, Hoffer, & Bostrom, 1990; Kim & March, 1995).

Some studies aimed at building cognitive models and explicitly characterizing the similarities and differences between experts and novices have been carried out (Batra & Davis, 1992; Sutcliffe & Maiden, 1992; Prietula & March, 1991); these have a more explicit focus on the implications of their findings for teaching and learning. In a similar vein, because information modeling is a cognitively intense activity, and as such it is susceptible to cognitive biases, i.e., errors that result from a misapplied heuristic (Tversky & Kahneman, 1982), some studies have been set up to identify biases both for experts (Siau, Wand & Benbasat, 1995) and for novices (Batra & Antony, 1994), in order to understand how to lessen their effects.

The most researched task has been conceptual data modeling, which is concerned with the semantic description of the domain entities, categories, attributes and their relationships, according to some data modeling language, typically the entity relationship model (ERM). The factors that account for novice errors, as identified in Batra and

Antony (1994) are: 1) combinatorial complexity of the task, 2) use of heuristics that lead to biases, and 3) inexperience and incomplete design knowledge of the novice.

Specifically, Batra & Antony (1994) locate the source of many errors in the misuse of the "*anchoring*" heuristics. Expert anchoring involves choosing an initial data model and then refining it; on the other hand, novices seem to be reluctant to make changes, and the initial model or hypothesis becomes fixed even if it contains errors. One particular case of anchoring is "literal translation,"i.e., the low-level heuristics of translating nouns to entities and verbs to relationships, without attempting to understand the nature of the relationship; this leads to sub-optimization in the model. Other instances of anchoring are the by-product of other biases: 1) misuse of the relationships that are encountered more frequently and are easier to understand; 2) data saturation, or prematurely stopping considering other information as a consequence of information overload; and 3) order effects, i.e., aspects of the problem description encountered close to each other in time are related while those encountered separately are not. The errors that result from incomplete design knowledge, on the other hand, mostly concern the connectivity of the relationships and failing to use generalized structures.

One explanation for the problematicity of the connectivity is that novices may be overly concerned and spend more effort in deciding whether a relationship between entities is mandatory or optional, an issue which is quickly solved by experts by opting for the safer alternative (Siau, Wand & Benbasat, 1995). Siau et al., also point out the importance of *familiarity with the domain* in performing the modeling task, given their finding of increased uncertainty, even for expert modellers, about the correctness of the model when uncommon words were used in the description of the problem.

Concerning the use of process modeling techniques such as the data flow diagram (DFD), which place emphasis on procedural decomposition and top-down development, a familiar problem is the *ad hoc* nature of the process of top-down development itself, and the fact that the formalism does not provide formal rules about the semantics of process decomposition nor does it give guidelines about when the process should terminate (Ball, 1995). Indeed, two recurrent novice difficulties are *scoping the problem* and recognizing its boundaries, and performing *problem decomposition* (Sutcliffe & Maiden, 1992). These are two inherently ill-structured aspects of the analysis. Floundering in details seems to determine the difficulty in defining the problem boundary. Although one strategy to reduce the amount of detail addressed at any time is hierarchical abstraction, to abstract the critical properties of a problem (Simon, 1981), inexperienced students who apply it tend to follow depth-first strategies in elaborating the problem components, and then they have difficulty in coping with the level of detail generated. This phenomenon is reported in a protocol study of physical database design (Prietula & March, 1991).

Relatively more experienced subjects tend to spend more time in understanding the situation and information gathering before addressing representational aspects, and have "richer vocabulary and relative ability to categorize problem descriptions into standard abstractions" (Batra & Davies, 1992). The problem of *genericity of vocabulary* has been observed also in the designs of students who choose personally the problem to tackle for their course projects, their universe of discourse being rarely so developed as to capture effectively the specificity of the organization (Faro & Giordano, 1996).

One major finding in Sutcliffe and Maiden (1992) is that the critical determinant of success in analysis seems to be the ability to "*reason critically and to reason* *effectively with a conceptual model*", supported by hypothesis generation and testing, for example through the spontaneous generation of domain scenarios. In this study, the more effective subjects exhibited model-based reasoning, defined as cycles of hypothesis generation following a single thematic strand, while incrementally developing the conceptual model. Analytical success was measured in terms of design completeness, under the premise that novices tend to make more omissions than errors. This is a rather stable finding, also pointed out in Prietula and March (1991) and Venable (1996).

Model-based reasoning concurrent to the development of the conceptual model was interpreted as evidence of the formation in the subjects of mental models. Mental models (Johnson-Laird, 1989; Gentner & Stevens, 1983) have been postulated as a means to reason about physical or abstract systems whose behavior has to be determined when some characteristic of the system varies. They imply representations of the behaviors of the system that are simulated or "mentally executed" following qualitative judgments. Qualitative reasoning and mental models are also greatly emphasized as a key component of design reasoning to evaluate proposed design components and to evaluate the relevance and significance of the problem data (Prietula & March, 1991).

One common remark in the studies that have compared novice and experts is that the differences are mainly attributable to novices not having the strategies, specific task knowledge and domain knowledge to decompose the problem and to deal with complexity and detail (Batra & Davies, 1992). Also the markedly opportunistic and individually variable nature of the way of tackling analysis and design has been pointed out. Different strategies and heuristics can lead to successful solutions (Prietula & March, 1991). Prevalence of opportunistic versus methodic reasoning is also a consistent finding of the protocols in Sutcliffe and Maiden (1992), who show that the most successful subjects did not follow the well-ordered approach to analysis as advised by structured methods, but mixed analysis, design and implementation considerations.

Some comments are needed to cast the above results in the proper light. First it must be pointed out that such studies, by their very nature, do not take into account the social and collaborative universe that surrounds the real design practices and the real learning experience, in a time span that extends far much more than the time allocated to a laboratory experiment. Also, the specific effect of the particular notation and methodology used must be taken into account. In fact, one generalization that can be derived from those studies that are more driven by a human-factors perspective is that, granted the individual and opportunistic variations in strategies and performances, notational formalisms do make a difference concerning the semantic performance in the modeling activity (e.g., Kim & March, 1995) and can also inherently bias the approach to analysis towards one particular strategy , e.g., top-down refinement (Jarvenpaa & Machesky, 1989). In fact, some difficulties are not necessarily related to a specifically novice kinds of reasoning or lack of knowledge, but, more simply, are induced by issues such as the visual salience of the notation (Jarvenpaa & Machesky, 1989) or the fact that the relevant specifications are distributed over different documents, which increases failures in understanding requirements specifications, detecting specification errors, or identifying the influences or effects of changes (Takahashi, Oka, Yamamoto, & Isoda, 1995).

A summary list of the specific novice biases and difficulties hindering modeling and design performance which were highlighted in the above discussion is reported in Table 1.

Table 1. Recurrent difficulties and biases of novice analysts and designers

Key difficulties:
1) Scoping the problem and performing problem decomposition
2) Generating and testing hypotheses about the model of the system by robust problem-solving strategies (heuristic-based reasoning, or use of domain scenarios); mental model formation
3) Reasoning on model completeness (more omissions than errors)
4) Lack of strategies for dealing with complexity
5) Lack of familiarity with the domain
Biases/errors
1) "Anchoring": fixing the initial model or hypothesis, failing to detect errors or weaknesses
2) Piecemeal modeling by "literal translation" of nouns to entities and verbs to relationships that leads to design sub-optimization
3) Biases related to information overload, data availability (only what is easily available in the problem gets incorporated in the model) and lack of feedback
4) Tendency to concentrate immediately on implementation issues at the expense of high level analysis concerning the requirements
5) Working at too detailed a level
6) Lack of specificity in the universe of discourse

Some have proposed to teach data modeling by making the students aware from the very beginning of expert strategies and capabilities (Venable, 1996). What is arguable about the approach is the assumption that such expert strategies are teachable *tout-court*, without an explicit intervention on specific aspects that make the process ill-structured and difficult for novices. Also, taking into account the natural variation in the individual approaches and strategies to design problem-solving documented in the studies discussed above, it seems that this would not be productive. More sensible is the suggestion that, at least concerning the documented biases, students can be warned concerning the biases about what not to do, rather than being simply told what to do (Batra & Davies, 1992). However, as pointed out in the section to follow, there can be more sophisticated ways, both from the pedagogical and methodological point of view, to address the issue more directly.

2.3 Limitations of traditional approaches to teaching IS analysis and design

A traditional way of teaching IS analysis and design in the classroom is to illustrate the design methodology and then have the students apply it to case-studies describing some organization. Although this is a good exercise in technique application, it is not sufficient for developing robust skills in the identification of relevant processes and data because this sort of information is already embedded in the case, filtered by its author. Also, it is very demanding to transform individual IS case-studies into shared objects of classroom discussion as in the traditional case-method (Williams, 1992), because their complexity and representational format (diagrams, notations) make them not amenable to concise presentations to a very large audience. In the context of IS analysis and design four components of the cognitive apprenticeship pedagogical model (Collins, Brown & Newman, 1989) are especially crucial: the instructor modeling the task, the learners practicing authentic tasks, supporting metacognition, and having the learners explicitly articulate their knowledge. However, the implementation of such components/guidelines has some challenges. The first is that although the instructor can focus the task modeling effort on the methodological and technical aspects of design, especially on the ill-structured ones, other tasks, such as the requirements elicitation and validation with the end-user, are inherently difficult to model in the classroom.

Concerning the authenticity of the task, the learners should work on some real client needs in order to experience personally the subtleties involved in requirements elicitation and get a sense of the complexity of real systems. Recently, a hypertextual simulation of an organizational scenario, to be explored by the student who is required to exercise observation and requirements gathering skills, has been proposed (J.E. Kendall, K.E. Kendall, Baskerville, & Barnes, 1996). This has the advantage of being experiential and engaging but has the limitation of addressing only process issues, and not grappling with substantial knowledge about organizations and classes of recurrent problems or patterns. Also, a computer-based learning environment to teach graphical user interface (GUI) design skills and client consulting skills has been developed as a module of a Systems Analysis and Design School for a consulting firm (Campbell & Monson, 1994), following the Goal Based Scenario (GBS) approach. A GBS recreates a scenario in which the learner is required to accomplish some motivating goals (in the above mentioned case, to produce three artifacts, i.e., a design documentation for a GUI for a hotel reservation system, a simple prototype of part of the system, and a memo informing the fictional client about various aspects of the design of the computing environment on which the system has to be implemented) which are structured in such a way that, to meet them, the students are required to build a pre-determined core set of skills and knowledge. The philosophy of the GBS approach is not to teach decomposed or decontextualized skills, but to organize the learning resources so that information is provided when the learners specifically ask for it, and to provide opportunities to learn from mistakes. A key strength of the GBS approach is to provide information to progress towards the goal in the form of "cases" or stories that can be told by experts, for example through videos, when asked by the students. The approach has proved suitable for learning "soft" and social skills (Kass, Burke, Blevis, & Williamson, 1993/1994). However, GBS are expensive to develop, because they entail organizing a knowledge base in terms of cases and stories and mapping it to a goal structure that can be followed by the learners according to different strategies.

With respect to authenticity, project-centered courses are a viable approach to the creation of learning experiences that are representative of some crucial aspects of the design problem-solving and knowledge construction process, including communication and team collaboration (Habra & Dubois, 1994; Moore & Potts, 1994; Bruegge & Coyne, 1994), because students can work in teams and a major emphasis is placed on the production of a real design artifact. This has also the benefit of cultivating analysis and design as a competence, not just a body of knowledge, and is a step towards developing reflection in action skills (Schön, 1983), i.e., those competencies that permit one to act and respond effectively in familiar situations, and reflective skills that let the practitioner reason about his or her skills and knowledge when the most immediate course of action seems likely to be unfruitful. The major strength of project based courses is the authenticity of the experience; however, drawbacks are time constraints, finding projects of adequate complexity, and the bias and tendencies that novices bring to the task. The first two drawbacks can be solved by GBSs, at the expenses of the authenticity of the "real" project, but the issue of the novice biases and difficulties is not explicitly addressed in either approaches: project-based or GBS.

Regarding the metacognitive aspects, the student should internalize both the heuristic criteria of good design and the verification mechanisms that are not implicit in the design techniques; this requires extensive practice, and experience with a variety of cases, as was pointed out . One way to encourage the students to think critically about their design solutions is by requesting them to articulate the rationale behind the decomposition of the system into specific functions or objects, and making the quality of articulation an integral part of the evaluation process. However, this begs the question of how to support the learner in reaching an adequate quality of explanation in a domain with a highly technical language and in which inferences from design and domain knowledge play a constant role.

One promising approach to support design is case-based reasoning (CBR) (Kolodner, 1993; Oxman, 1994; Maher, Balachandran & Zhang, 1995). Broadly, case-based reasoners solve problems by retrieving previous solutions that partially match the problem based on some similarity metrics, and proceed by adapting those solutions to the requirements of the design problem. Applications of case-based reasoning to database schema design (Paek et al., 1996) and to facilitate the designer in the re-use of requirements specifications (Maiden & Sutcliffe, 1996) have been proposed recently.

However, the effects of case-based reasoning approaches on learning are just starting to be investigated. In the context of learning a design practice, the possibility of inspecting a variety of design artifacts is useful because such artifacts embed technical knowledge about how certain design cases are solved and how projects can be structured and developed; the variety of cases can suggest more refined dimensions for analysis and help develop cognitive flexibility (Spiro, Coulson, Feltovich, & Anderson, 1988). In particular, it has been noted that although a base of cases can help the learner in seeing how knowledge can be generalized and transferred (Guzdial et al., 1996), only rarely do students adopt this approach spontaneously (Reimann & Schult, 1996). The possibility to elicit adequate learning processes as a side effect of interacting with a properly organized library of cases has been acknowledged (Reimann & Schult, 1996), and indeed the problem of case organization and indexing is particularly crucial in a learning context. If cases are organized according to abstractions of classes of design problems and relevant solutions, it might be a problem for the novice learner to identify the class to which a particular problem belongs. For example, a novice who is designing a reservation system might fail to recognize it as an instance of the abstract "resources allocation" case, and search accordingly in that class of problems (Faro & Giordano, 1997b).

The discussion above points out some directions that can be taken to construct a learning experience which integrates the strengths and the potential of each pedagogical approach, and attempts to mutually counterbalance the associated weaknesses and constraints. The proposed architecture tries to get some leverage by operating on the following dimensions: methodological approach to design, collaborative and social construction of cases, integration with the classroom pedagogy, and interplay between individual and organizational learning.

The following two sections aim, respectively, at a) characterizing the improvements in supporting the learning process and some of the reasoning involved in design that can be obtained by operating directly at the level of the design methodology, and b) characterizing the learning affordances of building and using as a resource a shared design memory emerging from the design cases produced by the students.

2.4 Anchoring the learning process to story-based design

The languages and notations used in IS design do not facilitate tracing the evolution of scenarios that the system must instantiate; thus the verification of the semantic and dynamic aspects of the model is cognitively demanding. An essential requirement for the methodology to allow the novice designer to quickly engage in the design process is that it be cognitively adequate for remembering and organizing experience. The Story Telling Theory (STT) (Faro & Giordano, 1996, 1997a) was proposed as a way to formalize scenario-based approaches to design and as a means to support the learning process. This methodology provides a template to formalize the use-cases of the Information System in a set of stories and episodes that inherently take into account the user's point of view. It allows the designer to organize the requirements in such a way that propagation of effects among stories tends to be confined, thus allowing partial and incremental verification of the model and provides a contextualized framework that facilitates interpretation of the relevant data and process models.

The approach is supported by psychological theories that point out the fundamental role of narration in cognition. Some consider stories as fundamental for memory indexing (Schank, 1990), while others go a step further and consider them as the organizing principle of cognition even in the process of making sense of experience (Bruner, 1990). However, totally unconstrained narratives about the system requirements would result in design scenarios that were still relatively complex, because of concurrent and/or nested stories, the ambiguity inherent to the language, and the incompleteness of any specific point of view from which a story is told (e.g., a secretary's point of view differs from the manager's point of view in the specification of the office functions).

The STT (Story Telling Theory) "template" partially addresses the above issues by organizing narration according to a set of categories (WHO, the main actor of the story, WHAT, the goal of the story, HOW, the sequence of the episodes to perform to reach the goal of the story) augmented by a description of ASSUMPTIONS (episodes that are a pre-condition for the story to take place) and WHAT CAN GO WRONG (obstacles towards reaching the goal). Such descriptions allow the generation of focused strategies for EXCEPTION HANDLING or recovering from the obstacles, to let the story progress, or otherwise abort, and continue with some other story.

The "template" becomes a key tool in guiding the learner to acquire the metacognitive skills for correctly performing the requirements' elicitation process. From the student perspective, grounding their conceptual modeling exercise in the story telling approach to requirements collection affords some advantages : 1) the traceability between requirements and design solution; 2) learning to keep a user-centered perspective; 3) incremental deployment of the conceptual model, which helps performing correctness checks, and 4) easier identification and control of the dynamic behavior of the model. Points 1) and 2) are usually claimed to be the rationale behind approaches to requirements engineering broadly based on scenarios or use cases. Points 3) and 4) are especially important for a novice learner, for lessening the cognitive load involved in performing such task. Also, because reasoning by story telling is based on the natural ability to comprehend and structure stories the learner can immediately engage in the real task of elicitation and analysis with a clear vision of the overall goal of the design process and with a tool that facilitates communication with a real user.

Thus STT is a first support in breaking down design complexity, but still there is the somewhat arbitrary nature of the decomposition of stories in episodes and events. This is partly addressed by some decomposition rules provided be the methodology itself, based on the goal structure of the system. With respect to the other difficulties and biases reported in Table 1, it can be pointed out that, concerning the problem of generating and testing hypothesis about the model of the system (point 2 in Table 1), STT, unlike conventional methods, directly starts from the domain scenarios. The study of Sutcliffe and Maiden (1992) indicates that subjects who spontaneously use scenarios tend to be more successful in analytical performance, and thus STT tends to overcome differences in this aspect of analytical skills. On the other hand, biases such as working at too detailed a level, or piecemeal modeling, could be indirectly exacerbated by the STT approach, if each story or episode is simply "translated" into a partial data model or process model. STT suggests to address the optimization of the overall model when each partial model is integrated in a global view, in a process of bottom-up synthesis. Lack of specificity in the universe of discourse is not taken care of directly.

2.5 From case-based systems to shared design memories

By making available a repository of cases with student projects, some beneficial side-effects for the learners can be attained. Students can facilitate their design process by examining fully developed projects because they:

1) see concrete examples of application of the design techniques and get a sense of the scope of the exercise that they are requested to do;
2) can possibly analyze projects in the domain they have chosen (e.g., insurance, banking, medicine, travel agencies, etc.) to check the concepts, the language, and the procedures/functions embedded in the conceptual model;
3) can be exposed to a variety of design artifacts that embed technical knowledge about how certain design cases are solved and detect patterns of problem instances and solutions. Also, more refined dimensions for analysis can be suggested.

Besides facilitating the development of an initial design concept, ideally such a case base would also afford the opportunity to exercise critical skills, given that the design artifacts originate from novices and are likely to incorporate some misconceptions and thus discourage "blind re-use".

However, there is a limit to what can be accomplished by such a rudimentary case-based system. Interestingly, having access to former projects does not result in increased depth of analysis in the modeling of the organization (Faro & Giordano, 1997b). Indeed, the re-use of stories or episodes from other projects seems to result in a form of design stereotyping at too high a level of generality, with emphasis placed on detecting surface level analogies with other organizations, rather than on focusing on the differences, as truly user-centered design would require.

This may be the result of the fact that the cases available for inspection are developed by other novice learners and not by professional designers, but it can also be a result of the fact that by simply examining projects as independent and unrelated items, without having some information on their design rationale or on the underlying problem-solving and design process, which can only be inferred, it is difficult to develop a deep understanding for an informed resource re-use, and for a productive transfer of the design experience.

Thus, at the level of organizational learning there is a risk of promoting a certain degree of uniformity or encouraging the diffusion of incorrect or unproductive practices if the process of re-use is not backed up by some means to facilitate the interpretation of the meaning and value of each artifact. However, because the sort of information that is needed to do so bears fundamentally upon the social nature of the design process (Bucciarelli, 1994) it is very hard to recreate or represent.

This latter issue has been central to the problem of supporting organizational learning by making the knowledge embedded in artifacts, documents, or even that generated during live discussions, more resilient and more widely available to the potentially interested members in an organization, i.e., by enhancing the organization's "memory" (e.g., Walsh & Ungson, 1991; Giordano, 1994; Terveen, Selfridge, & Long, 1995). Efforts towards recording the rationale for decisions, especially those occurring in design meetings, have generated much research into languages and graphical notations for expressing the argumentation underlying the design decisions. This involves structuring the discussion that surrounds any particular design decision according to categories such as "support", "object", "goal" (e.g., Lee & Lai, 1991), and graphically mapping the relationships between facts, arguments, counterarguments, and so on, in an electronic medium. However, later intelligibility of the rich resulting picture turns out to be difficult even for those who participated, due to the lack of context or contextual clues

(Buckingham Shum, 1997). This makes even more difficult the transfer or "re-use" of that design experience across different projects or teams.

This objective representational difficulty is a natural constraint to the process of supporting the continuity of acquiring and transforming design practices across generations of design students. However, there are unique pedagogical opportunities in the process of transforming the repository of cases from a "commodity" to use, in a covert background activity, to the outgrowth of an acknowledged effort of the learning community for building a shared design memory.

First, the learners are introduced to a process of knowledge construction in which they have to take personal responsibility. Provided with a representational framework that is not excessively intrusive or cumbersome to use and that allows them to relate design cases and to express design reasoning, the learners can exercise the communication skills that facilitate transferring and re-using experience, in the effort to making their contribution as intelligible as possible even to those that did not share the context of its creation (Giordano, 1997b). This latter aspect is especially important in domains in which competence requires being able to participate in the collaborative efforts of an interdisciplinary team. As Bucciarelli (1994) points out:

> Expertise and competence within an "object world", are not enough to ensure quality design. All the participants must be able to explain and describe their experiences to others from different object worlds who do not have the same depth and expertise, or the same familiarity with underlying form and technical possibilities. (pg. 81)

Especially in the domain of design, in which there can be a marked creative and personal component both in the way of framing problems and of finding solutions, the fact that the design cases are shared provides a reference model regarding the quality that can be achieved. This can be a motivational drive for those learners who are truly novices to the field, and also for those who are more experienced and confident. Thus one element of educational leverage is provided by the means of creating individual "identities" as a designer in the space of the shared design memory, which implies being able to relate and differentiate one's own artifact from those that already exist (Giordano, 1997b).

To fully gather the potential educational benefits , the adopted representation and structuring mechanisms for the shared memory must be carefully tailored to the design domain, ensuring consistency with the sought after mode of discourse; embed some features that counteract the risk of uniformity: and respond to issues such as to what extent product and process must be represented in the memory, to enhance the meaningfulness of the information.

The object of the next chapter is to explain, first, how these issues have been accommodated in the architecture of a shared design memory for information systems analysis and design, taking into account the novice biases and difficulties referred to earlier, and then to present the research model adopted to investigate it.

Chapter 3

StoryNet: Architecture and Research Model

This chapter first presents the architecture of StoryNet (Giordano, 1997a ; Faro & Giordano, in press). StoryNet is a shared design memory aimed at supporting both individual learning (by enhancing the ability to carry out a deep, user-centered analysis of the business organization, and the ability to critique and verify the design) and organizational learning (by facilitating the circulation, acquisition and transformation of design ideas and practices). The thrust of the description provided in Section 3.1 is to explain how the StoryNet architecture addresses the issue of providing enough context around the design cases to make them meaningful and useful to the learners, and how it operates in conjunction with the methodological approach to design to possibly offset some of the errors and biases which the novices tend to incur. Then Section 3.2 gives some information about the context of deployment. The core of the chapter, Section 3.3, illustrates the model adopted for exploring the effects that StoryNet has had on the "generations" of students who have participated in its creation. Finally, Section 3.4 describes the instrument used for gathering individual information, and sets the ground for the results presented in Chapter 4.

3.1 The architecture of StoryNet

StoryNet can be characterized as an evolving system, made up of a network of annotated design cases incrementally linked by the students. In the context of learning IS design it is desirable to view projects from different angles, e.g., as the analysis of a particular kind of organization, as a solution more or less adequate and innovative of specific classes of problems, as exemplifying typical mistakes, as clarifying the relationship between analysis and design, for example, in sketching the user-interface.

The general motivations for organizing the cases in a hypertext network in which links connect cases that share some aspects and thus allow thematic exploration are given in Spiro et al. (1991). Essentially, it is argued that such hypertexts (cognitive flexibility hypertexts) allow one to see how aspects are interrelated in ill-structured domains, thus fostering in the learners analysis skills and, possibly, cognitive flexibility, defined as the capacity of flexibly assembling knowledge components relevant to solving problems. Some evidence concerning an increased ability in analyzing a problem according to multiple dimensions as a consequence of using hypertext based instructional systems is given in Jacobson and Spiro (1995).

However, in cognitive flexibility hypertexts, aspects and themes are identified in advance, and links are deployed accordingly by the designers of the hypertext. who also select the cases. An environment for design is too constrained if the resources it contains and their links are pre-defined, because this would embody an *a priori* design theory and set of principles. This is even more true of information systems design which is a wide, multifaceted domain subject to fast changes in the technologies. "Prepackaged" case-bases can become obsolete very quickly and thus do not allow the learners to develop the ability to interpret and design according to changing organizational and business realities. On the other hand, the challenge of the shared design memory is just to deploy mechanisms that allow for the dynamic collection and organization of design resources, for emergent design principles.

The prime organizing theme of StoryNet are "*stories*" and "*episodes*" that model the organization, following the STT design methodology outlined in Chapter 2. Attached to these stories and episodes are multimedia documents illustrating the data models and snapshots of the user-interface of the implemented prototype (Figure 1). By examining cases organized in stories and episodes, their structure can be readily perceived, but not the motivations underlying that structuring, or other considerations that were made during design reasoning. These considerations can be made more explicit in "*comments*" attached by the authors to each specific story or episode, or in "*links*" to the precedent design cases that were used (if any). Comments and links explain how the current design solution evolved based on the suggestions or in the errors to avoid detected in the precedents. This exercise requires a more focused effort to place the contribution of the new design case in context, and this is an opportunity to foster in the learners specificity in the analysis and exercise communication skills.

In the same spirit, an additional component of the shared design memory comprises the "*design critiques*" that are attached to the design representations. Such critiques are contributed in a structured document which addresses various dimensions of the quality in the design. For each dimension different aspects are suggested that might be taken into account to justify the overall judgment. These guidelines were developed as an implicit model of how an expert would approach the evaluation of the design. In Appendix A there is a copy of the review document as available in StoryNet.

The philosophy of the shared design memory is that there is some added value in sharing such documents beyond the process of producing them. Accordingly, the reason for sharing the critiques is that they have potential to provide a contextualized representation of the possible weaknesses in the reviewed precedents, and to function as an intelligible and illustrative warning for newcomers in selecting the more useful precedents. The load of creating such resources is distributed among the students and since each design team reviews at least one precedent, as a course requirement, a representative sample of the biases and misconceptions can be generated. Also, the proposed mechanism fundamentally relies on the differences in competence and sensibility that are normally found in a wide population of learners (typically, in the context for which StoryNet has been designed, about 25% of the learners already have some professional experience). This ensures enough variety in the cases and in the way design is tackled, and in the insightfulness of comments and reviews, to be valuable to beginners.

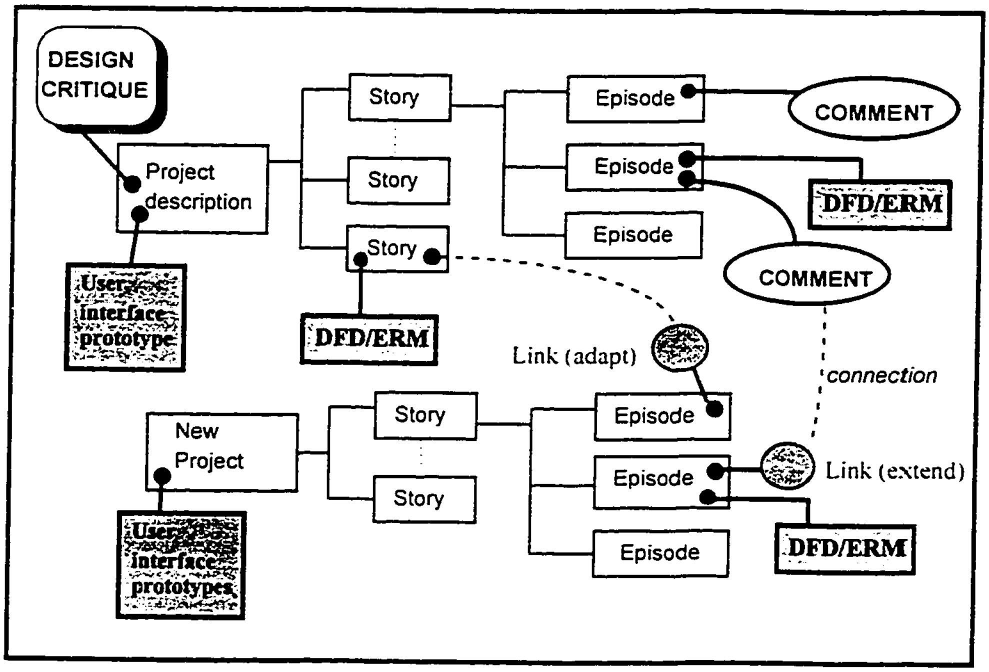


Figure 1. The StoryNet architecture.

Cases in StoryNet are incrementally linked in a network of "old" and "new" related design cases that highlight how design solutions have evolved. In some respects, the process mimics the use of citations and referencing in the scientific process. For each design unit that can be retrieved from StoryNet, its reference links point to other units (stories or episodes) that have been used or taken into account in the design of the retrieved unit and its citations links point to the more recent projects that have taken that unit into account. Links are typed to make more readily apparent how and why that unit was taken into consideration. Available typed links are: 'Correct', 'Extend', 'Detail', 'Adapt', 'Use as is', 'Restructure', 'Other'. Links are mediated by nodes that further qualify the typed conceptual link, by including an additional comment or "explanation". The annotated references of the project should make apparent the analytical and critical effort invested by the student (or a team) in the project, and his or her personal contribution in structuring and introducing the new design cases.

The structure "domain-story-episodes" provides a user-friendly indexing mechanism, and stories or episodes can be searched selectively according to the specific categories of the STT template. Full text search on all the documents in the shared memory is available, and once a first set of design cases has been identified as the result of querying the system, the links support navigation in StoryNet to find relevant design cases by exploring the surroundings of each case. In particular, the supported exploration strategies run backwards, in search of design rationale, and forward, in search of critiques and new developments. StoryNet is implemented on Domino Lotus Notes, a current groupware technology.

The hypothesized influence of some of the design features of the shared memory on the novice biases/difficulties in the relevant design activities is sketched in Figure 2.

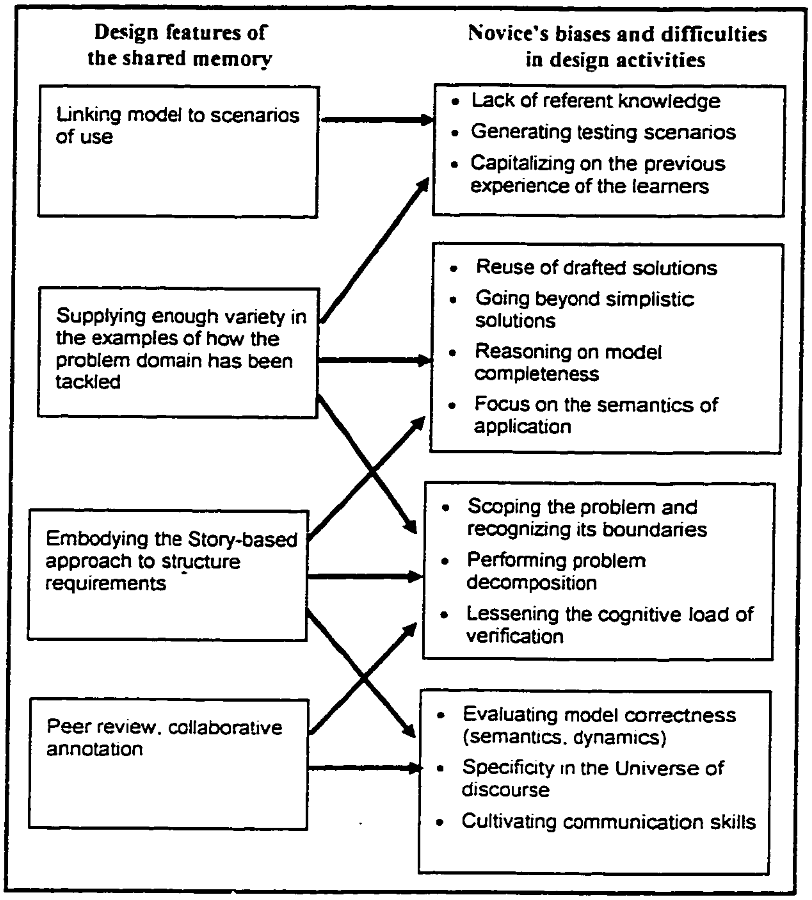


Figure 2. Hypothesized influences of some features of StoryNet on typical novice biases and difficulties in design activities.

The next set of illustrations provides a walkthrough of StoryNet. In Figure 3 is the StoryNet home page, and Figure 4 offers a view by title of all the Projects contributed to StoryNet. Figure 5 shows how to examine the organization of each project in the relevant stories. Figures 6 and 7 illustrate, respectively, the summary description of a Project with some of the attached design representations, and the specific description and diagrams of a story. Figure 8 shows the result of a search for design cases dealing with the registration of card-carrying members of an organization. Figures 9 shows the general view to access the comments and Figure 10 shows one comment that explains the link deployed between two stories of two different projects. Figures 11 shows a view of the citation links of the design cases, with the context of citation and, finally, Figure 12 shows a view of the critiques relative to each design case.

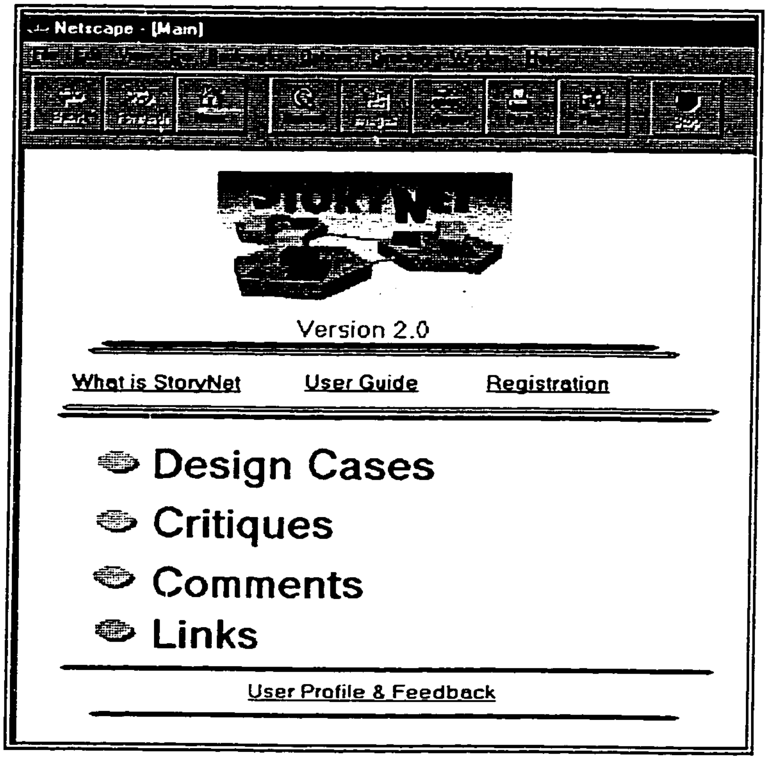


Figure 3. StoryNet home page.

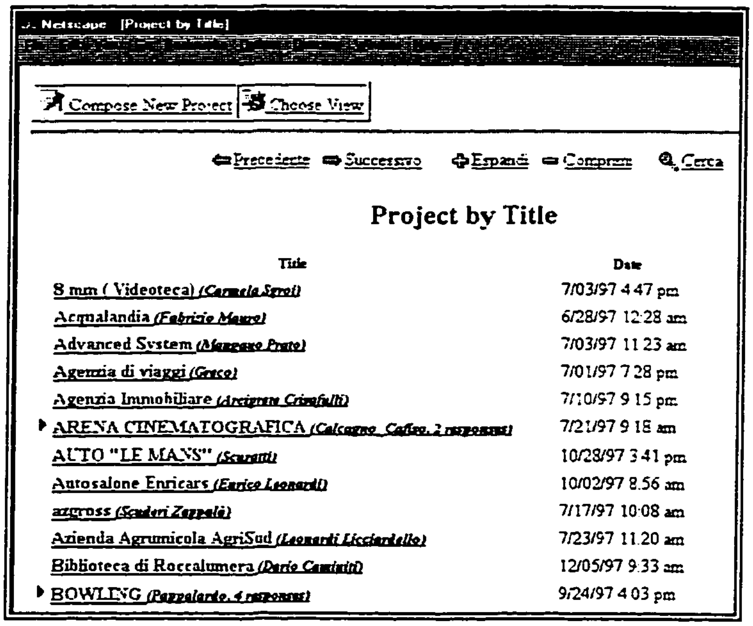


Figure 4. View of the design cases by title.

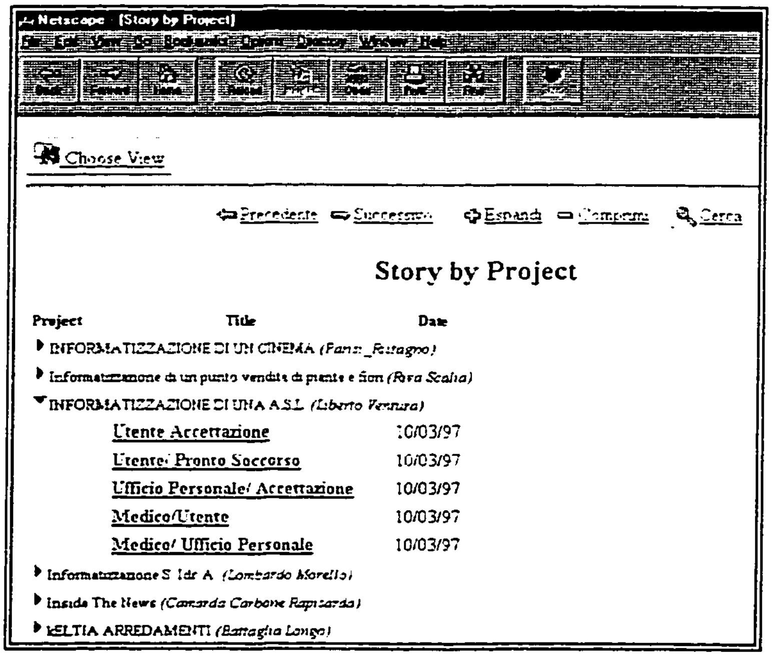


Figure 5. Stories pertaining to a project.

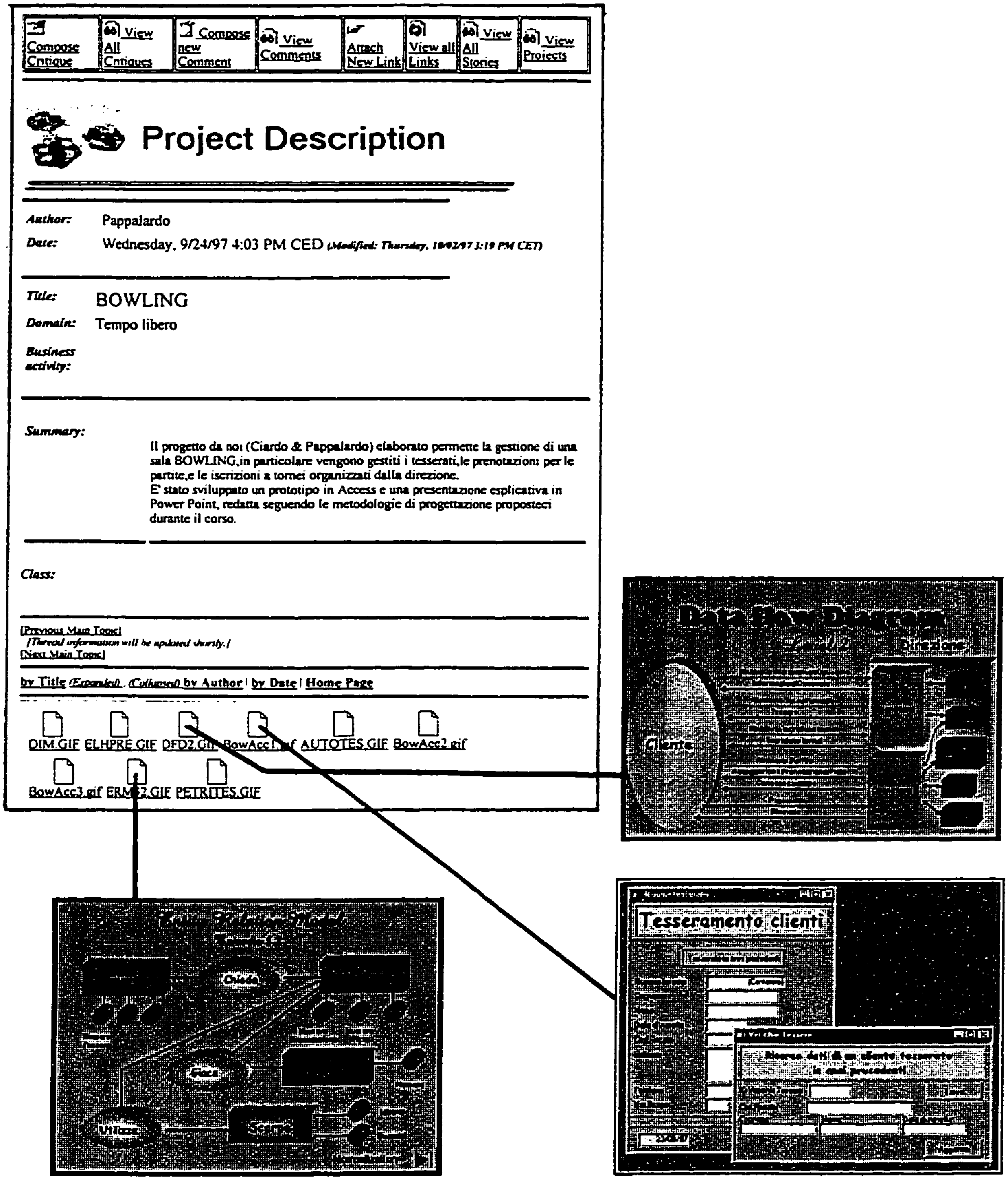


Figure 6. Project description, with attached DFD, ERM and a snaphot of the prototype interface.

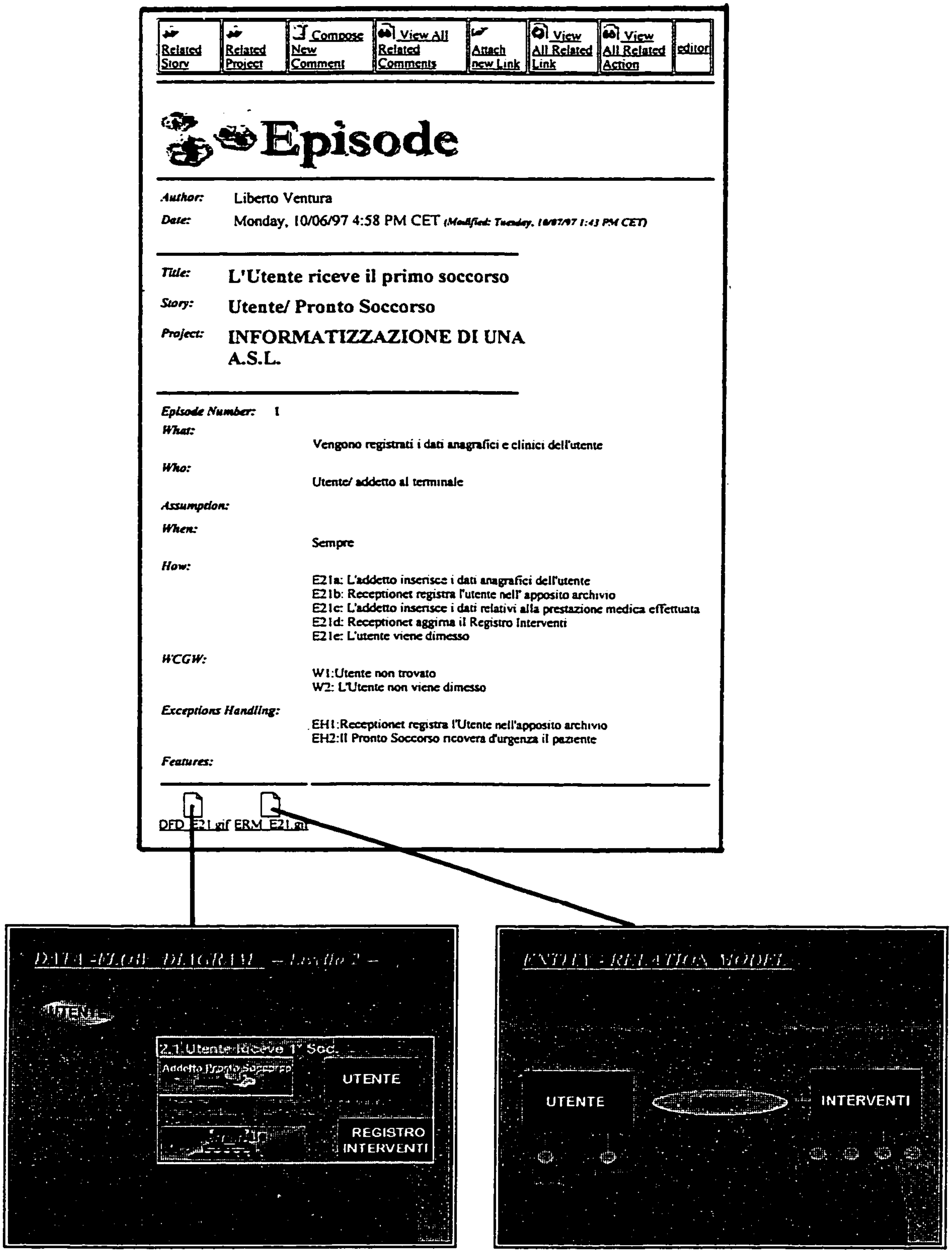


Figure 7. Episode template with attached the relevant partial ERM and DFD.

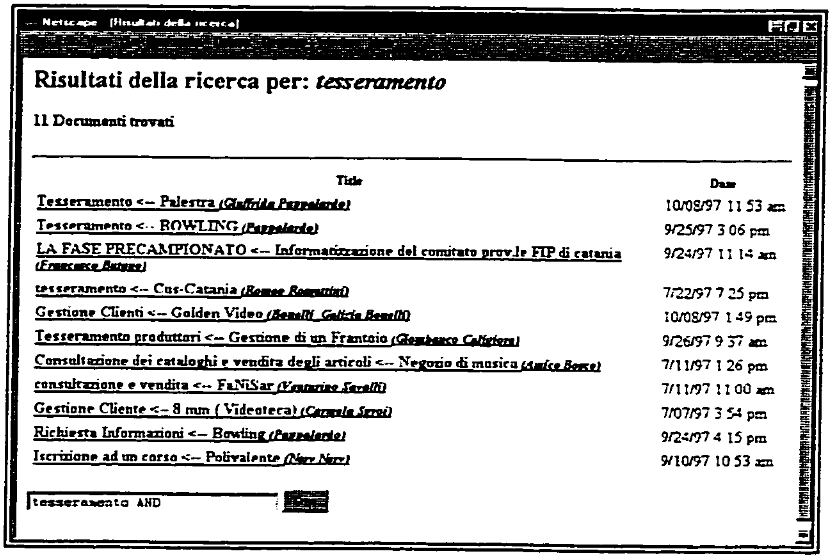


Figure 8. Results of a search in StoryNet.

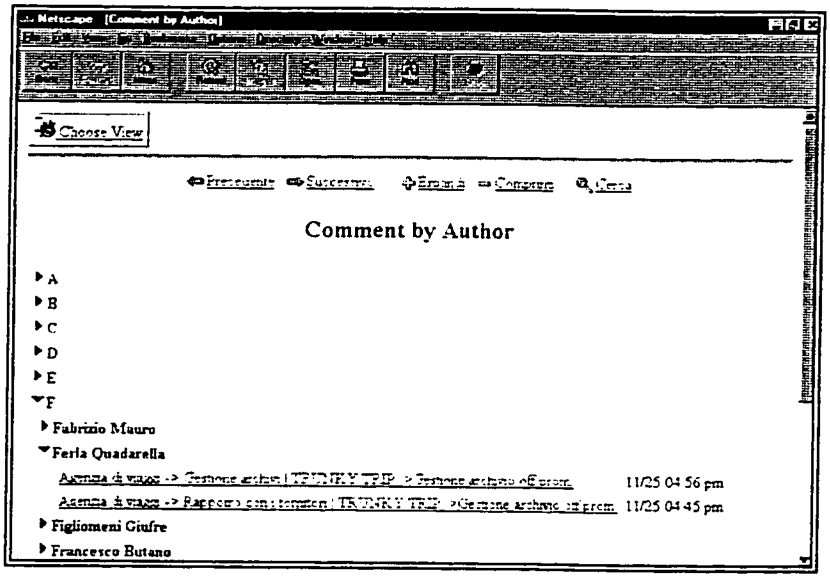
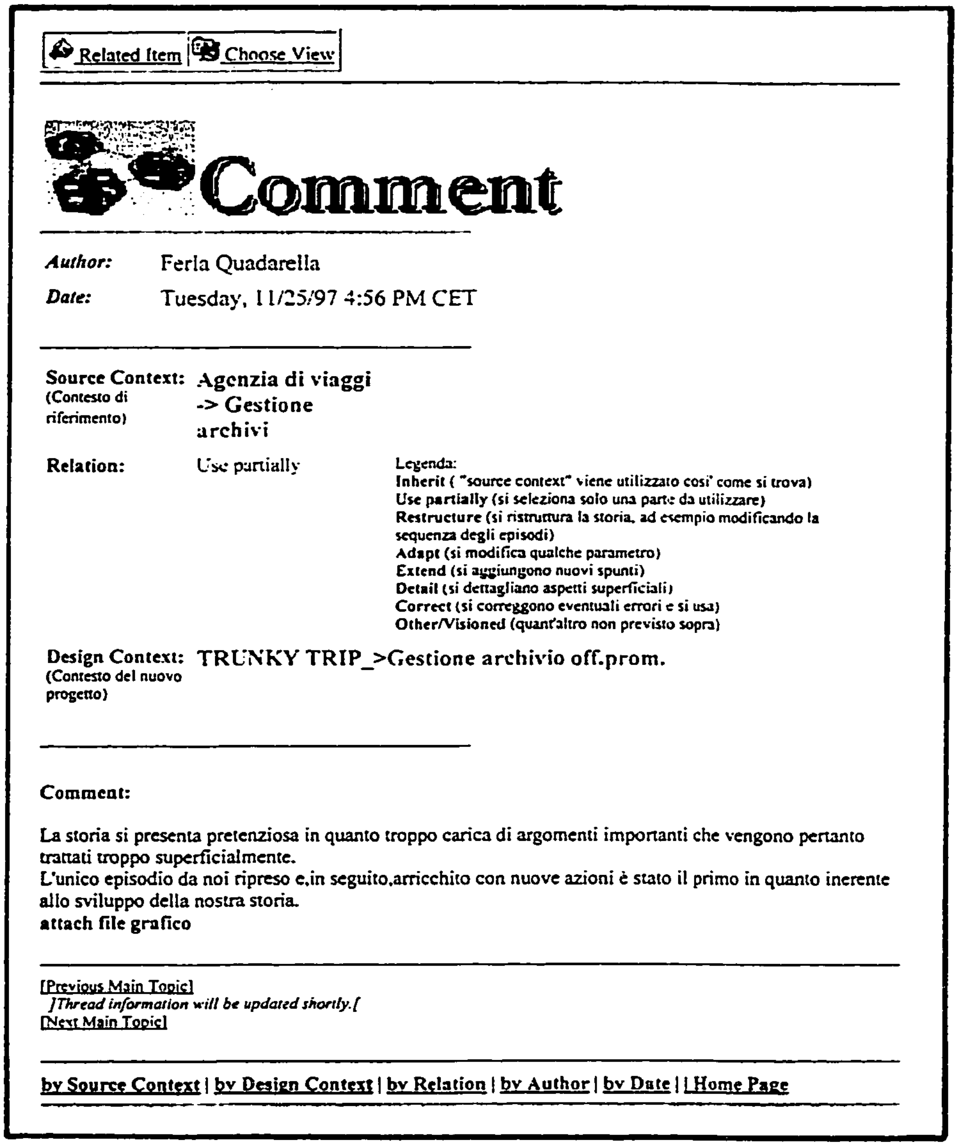


Figure 9. General view to access the comments to the design cases.


Related Item | Choose View

Comment

Author: Ferla Quadarella
Date: Tuesday, 11/25/97 4:56 PM CET

Source Context: (Contesto di riferimento) Agenzia di viaggi -> Gestione archivi

Relation: Use partially

Legenda:
Inherit ("source context" viene utilizzato cosi' come si trova)
Use partially (si seleziona solo una parte da utilizzare)
Restructure (si ristruttura la storia, ad esempio modificando la sequenza degli episodi)
Adapt (si modifica qualche parametro)
Extend (si aggiungono nuovi spunti)
Detail (si dettagliano aspetti superficiali)
Correct (si correggono eventuali errori e si usa)
Other/Visioned (quant'altro non previsto sopra)

Design Context: (Contesto del nuovo progetto) TRUNKY TRIP_>Gestione archivio off.prom.

Comment:

La storia si presenta pretenziosa in quanto troppo carica di argomenti importanti che vengono pertanto trattati troppo superficialmente.
L'unico episodio da noi ripreso e,in seguito,arricchito con nuove azioni è stato il primo in quanto inerente allo sviluppo della nostra storia.
attach file grafico

[Previous Main Topic]
]Thread information will be updated shortly.[
[Next Main Topic]

by Source Context | by Design Context | by Relation | by Author | by Date | | Home Page

Figure 10. A comment contributed by a design team.

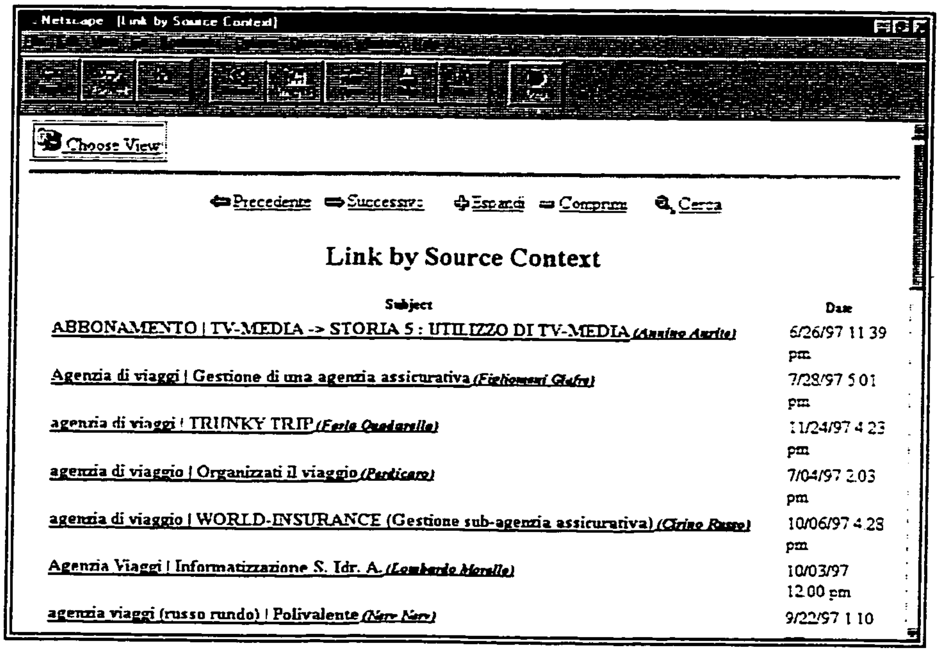


Figure 11. Citation Links and context of citations.

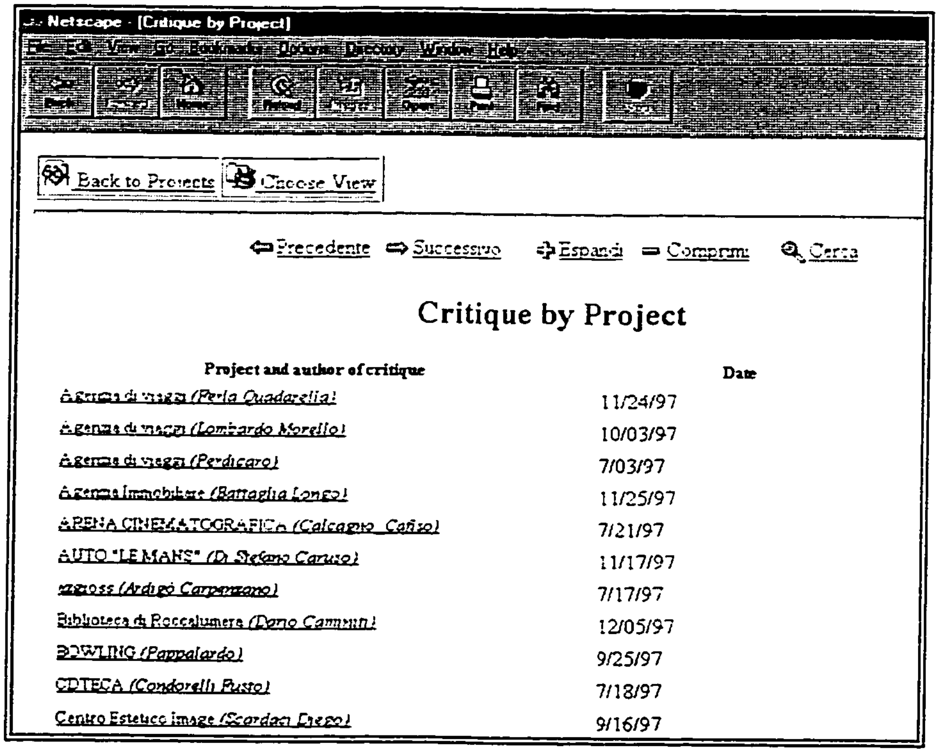


Figure 12. View of the critiques associated to the design projects.

3.2 The context of StoryNet deployment

StoryNet was deployed to support the undergraduates preparing for the course "Information Systems Analysis and Design" in the electronics and information engineering degrees at the University of Catania, Italy. The researcher was a participant observer in the experience, playing the role of teaching assistant of the course. The students in the course are usually students in their second year, although some students (typically 15% - 20%) can be at a more advanced stage in their studies. They have a very varied background in terms of former schooling and level of experience (amateur or professional) with some contents of the course. The main coursework requirement is the development of a project, involving the analysis and design of an information system and the development of a software prototype of one portion of it. The project can be developed collaboratively and is normally carried out by teams of two students.

At the time of deployment, the students were informed of the purposes for which the course's shared memory had been conceived and of its intended use and that they would be directly involved in building and using it. In explaining to the students the rationale for building StoryNet it was emphasized that the shared memory would be, on the one hand, an opportunity to access more design precedents, and on the other hand, an opportunity to make apparent and public in what respects the new designs were improved or original, and an opportunity to exercise design critique skills. The experimental nature of the intervention was also pointed out, both from the pedagogical point of view and from the point of view of considering StoryNet a form of advanced information system currently of topical interest for research. It was stated that students' feedback was invited and would be very welcome on any occasion. It was clarified which documents had to be contributed to StoryNet as part of the course requirements. Concerning evaluation of the overall contribution to StoryNet, the students were told that the criteria focused on the quality of the design review and on placing informative links. For those students who attended the course in former years and had not taken the exam yet, contribution of the required documents to the course memory was optional. During office hours the students could discuss with the teaching assistant the project that they want to develop, either individually or in teams, and the teaching assistant would select from the repository of former projects one or two projects, if any, that might be relevant to the topic selected by the students. This "manual" procedure stemmed from the need to start populating the shared memory with cases. It was recorded who was given what. One criterion followed in assigning the projects for review was that preferably the same project would not be assigned to more than two groups. The students were warned that such projects could be used only for didactic purposes and that there was a limit to the re-use that they can make of them in their design exercise. At the beginning, it was specified that no more than 50% of the stories and episodes of a precedent could be re-used, in order to make it clear what were the new contributions to the design. However, this was couched more as an indication rather than as a constraint, to emphasize that the key point was achieving a design with a distinctive mark, either in the domain application or in the solutions adopted. The students agreed to insert in the shared memory at least one of the projects that they had reviewed, and then they (individually or as a group) would attach to it their own critique (peer review), besides contributing their new design project. The students were given a document with the guidelines to critique a project (a mockup of what they would find in StoryNet) and they were also encouraged to add to the critique any other dimension that they may feel relevant. Technical training on the use of Storynet was provided with the following format: one class was devoted to provide a global view and illustrate its main use cases, and then four demonstrative session of 45 minutes each with smaller groups of students (each group of about 30 participants) were given. Extra clarifications or demonstrations were also given during office hours by the teaching assistant.

Customarily, at the end of the course, the students can choose when to take the exam (there are regular convocations every two weeks). When ready, they submit an electronic copy of their complete design exercise and present themselves for the exam, which is public and includes a detailed discussion of the project with the professor of the course. The examination usually takes about 45 minutes and addresses the analysis, design, and prototyping skills that the candidates have developed. The focus is on the ability to justify design solutions. This time the students were required to complete their contribution to the shared memory three days before taking the oral examination, to allow checking of the contents. The researcher was also present at the oral examination, asking questions, and taking notes about interesting aspects emerging from the discussions.

3.3 The research model

As a consequence of the perspective that a shared design memory is just a part of a distributed system, the study of its effects on individual and organizational learning must take into account dimensions pertaining to the design artifacts, the community of learners, and the shared design memory, as being an artifact itself. The overall learning environment's effectiveness in supporting analysis and design skills can be evaluated by traditional measures of quality of the design output, but a better picture must include also aspects related to the process of using this environment and how the overall process of designing, taking into account the shared design memory, is perceived.

The method chosen to carry out the study stems from the fact that, for some aspects, Storynet has to be studied with an ethnographic approach, to understand the social factors and the cognitive factors that govern the way it is perceived, used, and accepted, and in what respects it modifies the pattern of informal exchange of information and design artifacts among the students. This latter aspect can emerge fully only after the effects due to the start-up phase for populating StoryNet with cases disappear. At that point there should be enough content in the system to become appealing to students from the very beginning of their design experience. On the other hand, in the time span chosen for this study, that is from March 1997 to October 1997, other aspects, equally important, can be investigated to understand whether the pedagogical tenets of the overall approach hold. These aspects involve mainly the activities underlying the preparation of the documents to be shared on Storynet, i.e., the peer review, the annotated links, and the excerpts of the projects, and also the actual development of the project by taking into account the design precedents.

From a methodological point of view, the approach of this study differs from an ethnomethodological study involving a detailed observation of this background activity, maybe for selected groups, or from a protocol analysis study which would involve a detailed modeling of the reasoning processes involved in one specific task (of the many that are involved in finally getting a working software prototype) for a sample of the students. Because the focus of the study is not simply on the effects of StoryNet on the individual teams, but rather on understanding how StoryNet affects the process of knowledge transfer across and within "generations" of learners, the above approaches would miss the organizational learning effects concerning any trends of improvements of the whole community of learners. Thus the method of study is a cross-analysis of data originating from individual questionnaires gathered from the students, the contents of the shared design memory and the analysis of the final artifacts produced by the teams, occasionally integrated with their personal observations and recordings.

The model of "distributed system" upon which the research approach is molded is sketched in Figure 13 and illustrated in the following.

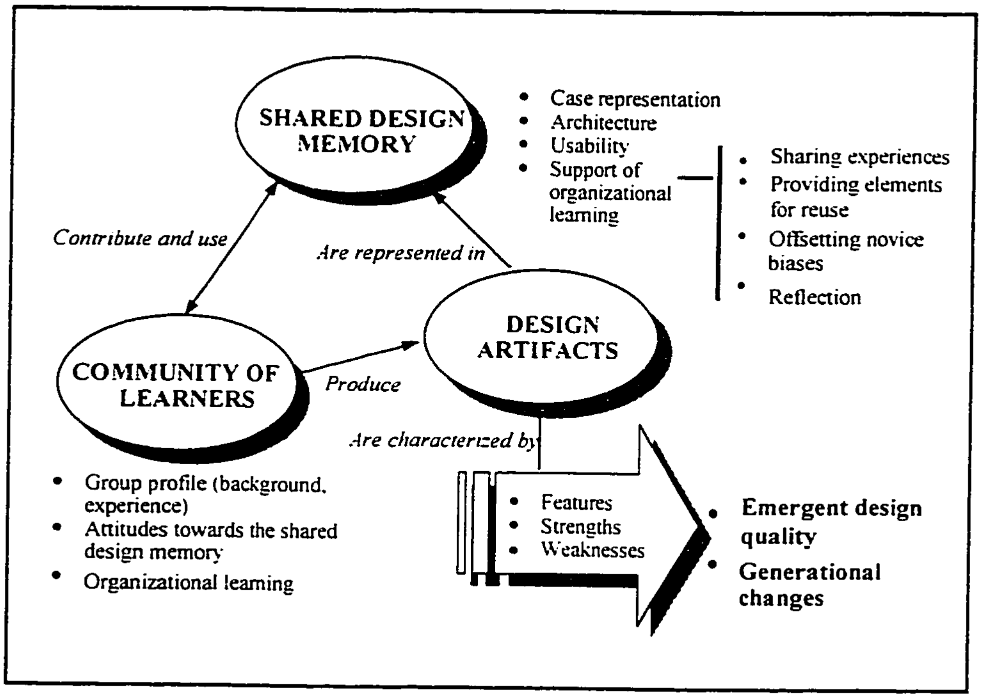


Figure 13. A model of the dimensions involved in studying the shared design memory.

Relevant dimensions to the community of learners are the group profile, the attitudes towards the shared memory, and the overall organizational learning of the community as a whole. Group profile must be considered when investigating the system because it can be a factor that affects the trends with which the overall system evolves, or that underlies possible failures of specific design or implementation features of the shared memory to correspond to their intended use. Level of initial competence in the design area of interest or in related fields is one aspect to normally include in the definition of the profile; as an heuristic criteria, any features that vary more extensively in the overall community, such as schooling background, interest in the subject, to name a few, might be worth attention. Conversely, those features that are strongly defining of the community have to be taken into account too.

Attitudes towards the shared design memory must be seen both globally, in terms of the community's acceptance of the system, and at the individual level, in terms of how each actor responds to the overall mode of dealing and thinking with representations enforced by the system. Thus one angle to investigate the students' perception of the shared design memory must regard the pedagogical rationale underlying the approach, i.e., the utility of viewing precedents, the utility of critically reviewing some of them and the utility of sharing both the precedents and such reviews. Another angle of analysis must focus on the effort or difficulty involved in the conceptual and communicative operations that are requested of the students in order to sustain and develop the contents of the shared memory. Finally, another angle of analysis must directly address the assumptions made by the designers of the shared memory concerning the effectiveness of the formats chosen to represent the precedents, to link them, and the solutions adopted to browse and to contribute to the system. Related to this latter angle of analysis and to the first one are preferences that the users of the system might express on any kind of information that they would like to see in the shared memory.

The organizational learning of the community has to be seen as an emergent effect of micro-activities such as sharing experiences between units that are solving problems collaboratively, re-using design elements, reflecting on the design process, and, overall, as a process of gradual enculturation in the modes of discourse of professional designers and in the "internal" modes of discourse generated within the community itself. But the key step is relating this global process to the quality of the design artifacts that are produced, to the generational changes that occur at each "cohorts" turn-over, expressed in the emergent overall design quality that stems from combining the design artifacts' features, strengths and weaknesses.

Indicators of the organizational learning that is taking place due to the introduction of the shared memory are: the kind of design features or solutions that have become standard (i.e., those that tend to be present in the majority of the more recent projects, whereas they were rare in a former generation), the degree of innovation, i.e., the percentage of projects within a generation that exhibit new features, and the number and type of design weaknesses, possibly related to the novice cognitive biases and difficulties, that tend to disappear or persist.

To highlight any trend of improvement, quality of designs can be compared to the quality attained in the former years, if the key elements in the pedagogical approach used have been kept constant, except for the introduction of shared memory, and the salient characteristics of the target population of students enrolled in the course for which the shared memory is implemented have not changed. Thus evaluation has an across-generations component and a within-generations component aimed at pointing out any differential effect that might be taking place. In this respect information about the group profile is essential to understand the limits of comparison and generalization.

Concerning the shared design memory, case representation, architecture and usability must be taken into account explicitly because it is necessary to see whether, beyond the raw cases, the quality of the additional representations (e.g., comments, reviews) is good enough to be conducive to the hypothesized effect of highlighting design strengths and weaknesses from many perspectives. This amounts to evaluating whether the community is able to produce such statements and to use them productively.

Based on the above model, the study is organized in two main parts. The first part is descriptive and uses the data relative to the students who participated in StoryNet from March 1997 to the end of July 1997 to characterize the student population, their attitudes towards the shared memory and the contents of StoryNet. In this time span more than 50% of the students who had attended the classes from March to May and who started actively working on their projects, presented themselves for the exam. Following the three angles of analysis illustrated in the model, this descriptive part addresses the relationships between individual characteristics, use of precedents, perceived difficulty of the design activities, and attitudes towards StoryNet. It also addresses the issues of how StoryNet serves as a means to highlight and show design weaknesses in context, and as a means to convey additional design knowledge through statements motivated and formulated to be useful also to future student readers. This part of the investigation is reported in Chapter 4.

The second part of the study addresses the actual quality of the designs produced by the students. It is a longitudinal study based on comparing the quality of design across three samples of 16 design cases each, coming from three generations: the 1^{st} generation, made up by the precedents available for review, the 2^{nd} generation, i.e., the new design cases produced in the time span until July 1997, and a 3^{rd} generation of designs, produced from September to November. This latter generation is introduced as a further test to evaluate the quality and stability of the effects achieved with the shared memory, once it becomes more consolidated. This comparison is followed by more detailed analysis concerning correlations within the quality dimensions of the 2^{nd} and 3^{rd} generation, and by an analysis of the design features that become diffused across the generations, also in relation to the design team profile. Also, three small case studies of "outliers" in the 2^{nd} and 3^{rd} generation are discussed, to complete the picture. The methodological issues involved in performing this analysis, are partly addressed in Chapter 5, for the aspects concerning the definition of design quality, the development of the instrument to measure various dimensions of design quality, and their mapping onto the novice biases. Then Chapter 6 presents the results relative to the second part of the study.

Before turning to the results of the first part of the study, the following section describes the instrument used to gather the individual information relevant to the angles of analysis identified in the research model.

3.4 Description of the instrument developed to gather the individual responses

The general philosophy underlying the design of the questionnaire was a) to elicit responses on an ordinal scale, either five point or seven point, according to the sensitivity required by the various aspects of the research model outlined in Section 3.3, and b) to supplement some of the most relevant questions with an open-ended section in which the respondent was asked to elaborate on the reasons for the rating expressed in the response. A copy of the questionnaire is in appendix B.

The questionnaire is organized as follows. The first section gathers demographic information, including at what stage in the program are the students, their GPA, and their level of interest in the subject. The students are asked to rate on a five-level scale (none = 1, novice = 2, intermediate = 3, advanced = 4, expert = 5) their experience or competence in: a) use of computers, b) programming, and c) database design. The specification "prior to enrolling in the university" for use of the computer and programming was used to better discriminate those who had long been practitioners, given that all the students enrolled in the course have already passed a pre-requisite programming course.

The second section of the questionnaire has a set of questions that, broadly, address the following topics: Design activities (questions coded with the letter D); use of Design Precedents (questions coded with the letter P); Critiques (questions coded with the letter C); Links (questions coded with the letter L); StoryNet (questions coded with the letter S); Team activity (questions coded with the letter T). In the following, a brief characterization of the questions for each topic is provided.

Questions D1-D10 (see Appendix B) probe into the perceived difficulty and criticality of different design activities. Questions D11-d13, at the end of the questionnaire, are open-ended and ask the respondent to comment on the most rewarding aspects of the design experience, on whether something would be done differently in approaching a new design task, and on any lesson learned worth sharing with peers.

Questions P1-P14 probe into the number, source and overall utility of the precedents examined before and during design. Questions P5-P15 probe into different cognitive activities that might be involved in examining the precedents and, indirectly, on the reasons that motivate the students to examine the precedents. The dimensions that are taken into account are: comprehension, analogy finding, abstraction of design rules, re-use and its effects on precision and innovation.

Questions C1-C14 deal with the perceived utility of the design critique exercise and with the utility of sharing the design critique in StoryNet.

Questions L1-L6 address both the technical and the conceptual difficulties that might be involved in deploying links among the precedents, and in communicating the underlying design reasoning.

Questions S1-S9 aim at eliciting the individual attitudes towards StoryNet, and address issues of usability and utility. In particular, the subsection from questions $S6_1$ to $S6_9$ addresses the relative perceive utility of examining the different kinds of representations that are supported in StoryNet.

Questions T1-T9 address the aspects related to the team's activities. One general question asked in this section is whether any of the team members had experience in the domain chosen for design. Other dimensions taken into account are whether the team was composed of members who had already worked together, and what approach was used in allocating tasks and responsibility among the team members.

All the questions were formulated to be non leading. The questionnaire was pilot tested with five subjects, and it required 20 minutes to be completed. The questionnaire was not anonymous, because some of the responses had to be correlated to the designs produced by the students, but it was confidential. Its purpose was clearly stated in the front cover. The questionnaire was administered at each exam convocation, and returned in a closed envelope at the end of the oral exam.

Chapter 4

From Individual Perspectives and Differences to Contents in the Shared Memory: a Cross-analysis

This chapter reports the results of the analysis of the data pertaining to the period that goes from the initial deployment of the shared memory, March 1997 to the end of July 1997. At this point the shared memory contained 34 new design cases, relevant to the course activity of the then current academic year. At that stage, 56% of the students had undergone the exam (64 students out of 114 enrolled in the course). Data reported in this chapter originate from the questionnaires collected from the above mentioned 64 students and from the analysis of the contents of StoryNet in the above time span.

The remainder of this chapter is organized as follows. First, in Section 4.1 there is a characterization of the student population. Then the next three sections address: the individual attitudes towards the shared memory and towards the use of precedents, in a broader sense (Section 4.2); the perceived difficulty and criticality of various analysis and design activities (Section 4.3); and the correlations among the set of responses and individual characteristics (Section 4.4).

Section 4.5 summarizes the results from the preceding sections. Finally, Section 4.6 presents the content analysis of the peer reviews contributed in StoryNet and a characterization of the information contained in the links deployed among the design cases.

4.1 Characterizing the student population

The indicators chosen to characterize the student population are: a) the level of experience in database design prior to the course; b) an index of overall competence in skills potentially relevant to the course prior to enrolling at the university, referred to as p.r. (previous related) competence; c) grade point average (GPA); and d) level of interest in the subject. Previous related (p.r.) competence was computed by summing the levels of computer experience, programming experience and database design.

The population of students can be characterized as having a strong interest in the subject, with only 22% declaring a medium interest, 55% a high interest and 23% a very high interest (Figure 14). Specific prior competence in database design has a majority of cases with no experience (63%), and is skewed towards the none – novice end of the scale, with these categories accounting together for approximately 80% of the total (Figure 15).

The level of experience with computers and with programming languages prior to enrolling in the university is more equally distributed over the whole range of the scale from none to expert (Figures 16 and 17), with only 11% of the cases having no prior experience at all with computers, and 23% of the cases having no prior programming experience at all.

As is shown in Figure 18, individual GPAs (grade point average) were distributed equally in the following three ranges: low [21 to 24]/30 (33% of the cases); medium [25 to 27]/30 (38% of the cases); and high [28 to 30]/30 (30% of the cases).

Of the 34 design projects, seven were carried out individually, 24 were carried out by teams of two members, and the remaining three were carried out by teams of three members. Those individuals who preferred to work alone (11%) did not differ with respect to the mean overall p.r. competence and mean GPA from those individuals who formed teams.

An analysis of how teams were composed was performed to highlight whether there was any unbalanced distribution of the team characteristics to take into account in the subsequent steps of the study concerned with the analysis of the achieved design quality. The distribution of the previous related (p.r.) competence of the individuals who worked in team is shown in Figure 19. Figure 20 shows at a detailed level how teams were formed according to whether members in the team had the same or a different level of previous related (p.r.) competence. The distribution shown in Figure 20, compared to the one of Figure 19, indicates a tendency of the students in the novice to intermediate range towards teaming with students in the intermediate to advanced range, whereas students with none or minimal experience mostly teamed among themselves. Figure 20 also highlights the wide spectrum of team typologies, ranging from cases in which both members had no experience at all to cases where members were, respectively, at the intermediate and advanced level. Fifty-eight percent of the teams were formed by students who had previously worked together.

An indicator of overall team p.r.competence was obtained by summing the scores of the members and recoding them into three levels. For the teams of three member the scores of the most competent two were summed. The resulting distribution is shown in Figure 21. The same distribution, factored by average team GPA, is shown in Figure 22. It indicates that the three types of teams had approximately equal proportions of students in the low and medium range of GPA; whereas the majority of the students with a high GPA were in the none to novice category of overall team p.r. competence.

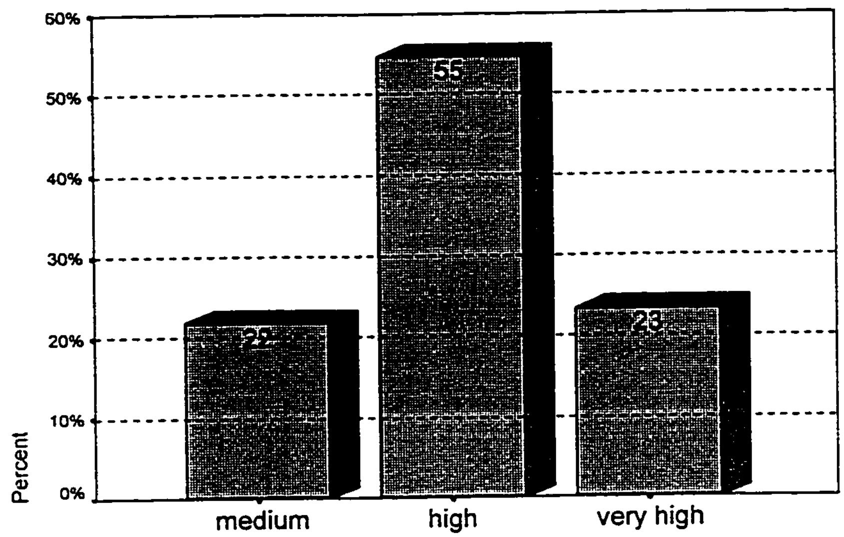


Figure 14. Individual level of interest in the subject.

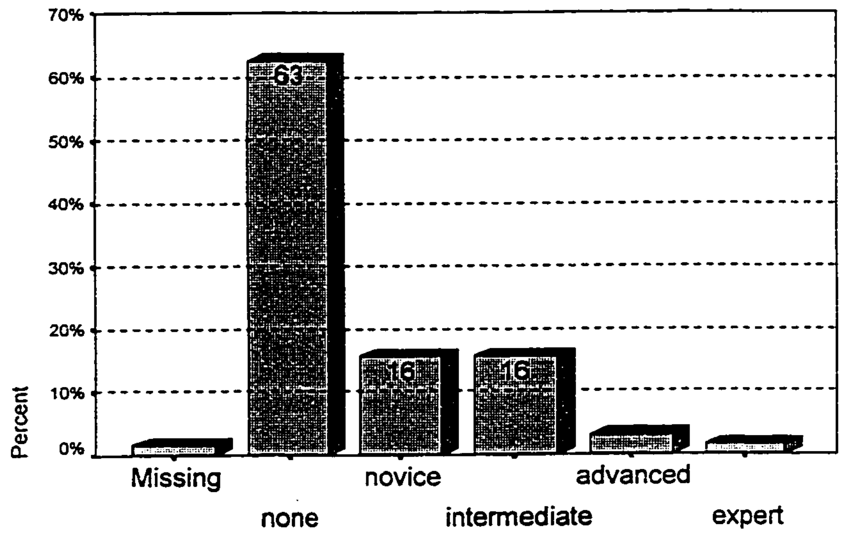


Figure 15. Individual level of database design experience.

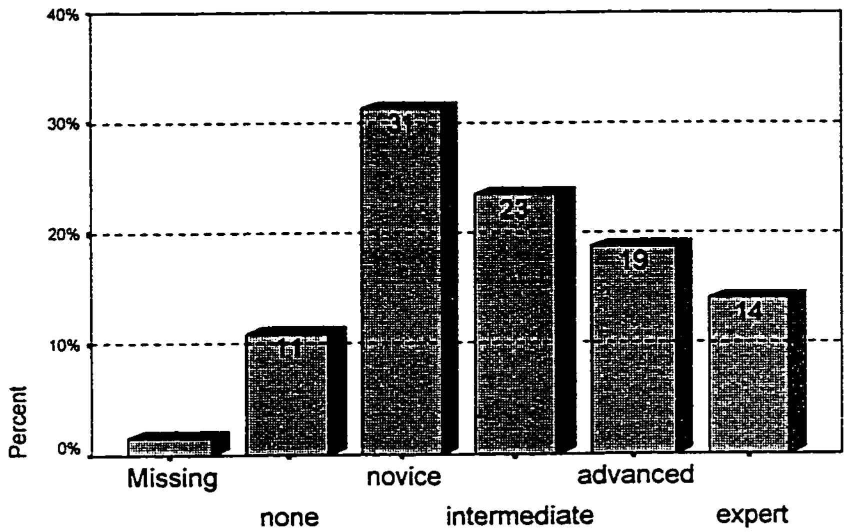


Figure 16. Individual level of computer experience.

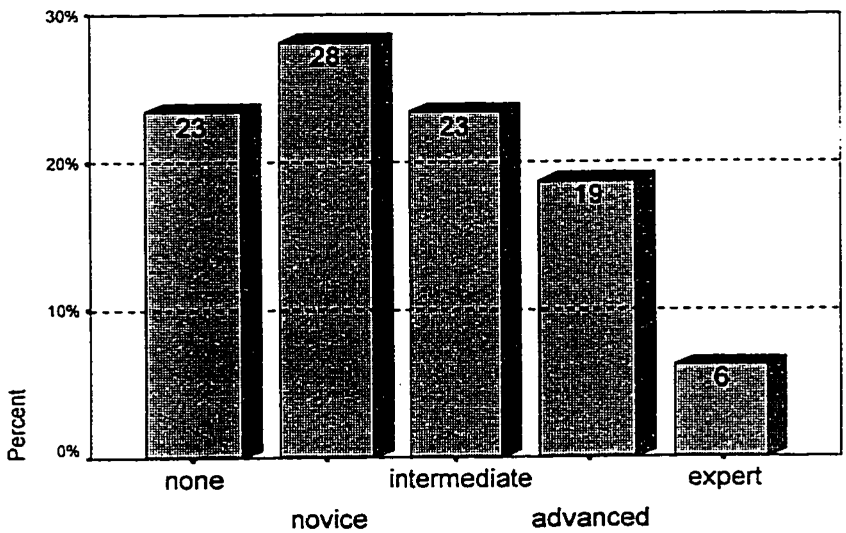


Figure 17. Individual level of programming experience.

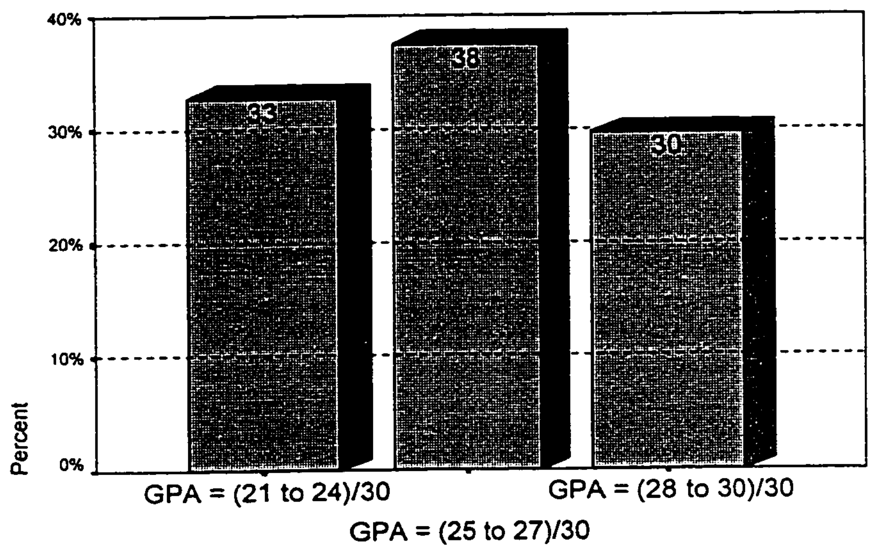


Figure 18. Individual GPA.

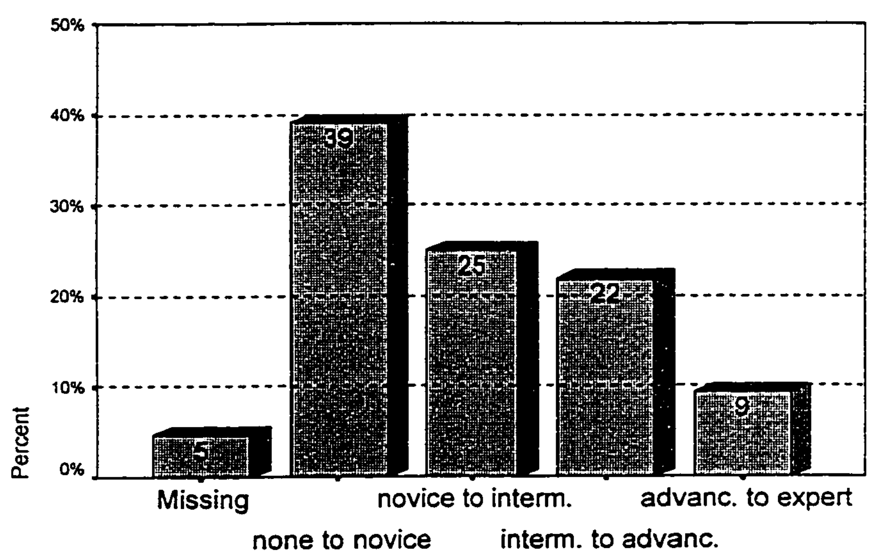
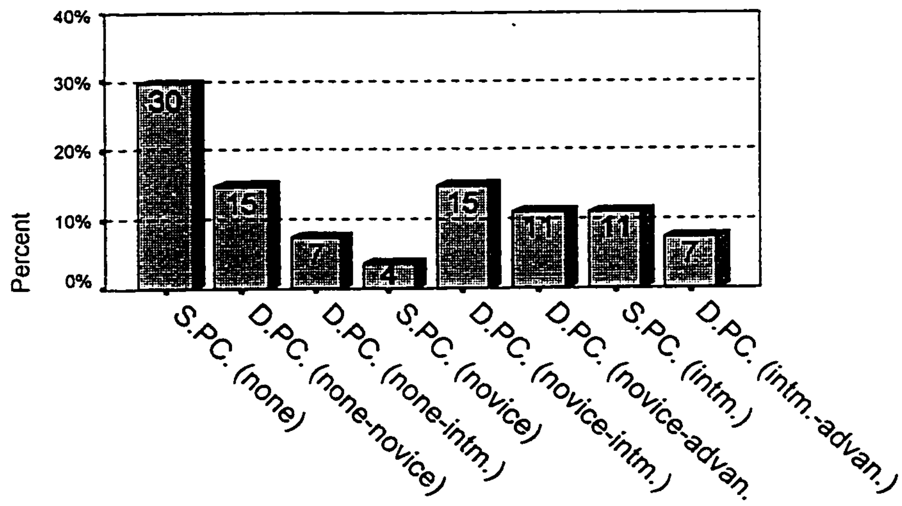


Figure 19. Overall p.r. competence of individuals forming teams.



S. PC. = Same p.r. competence (level)

D. PC. = Different p.r. competence (levels)

Figure 20. Levels of individual p.r. competence in teams.

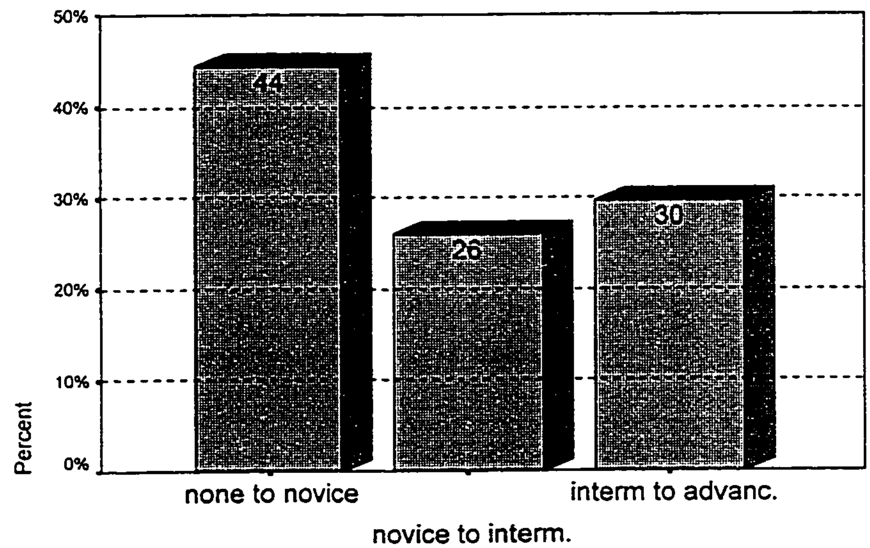


Figure 21. Overall team p.r. competence.

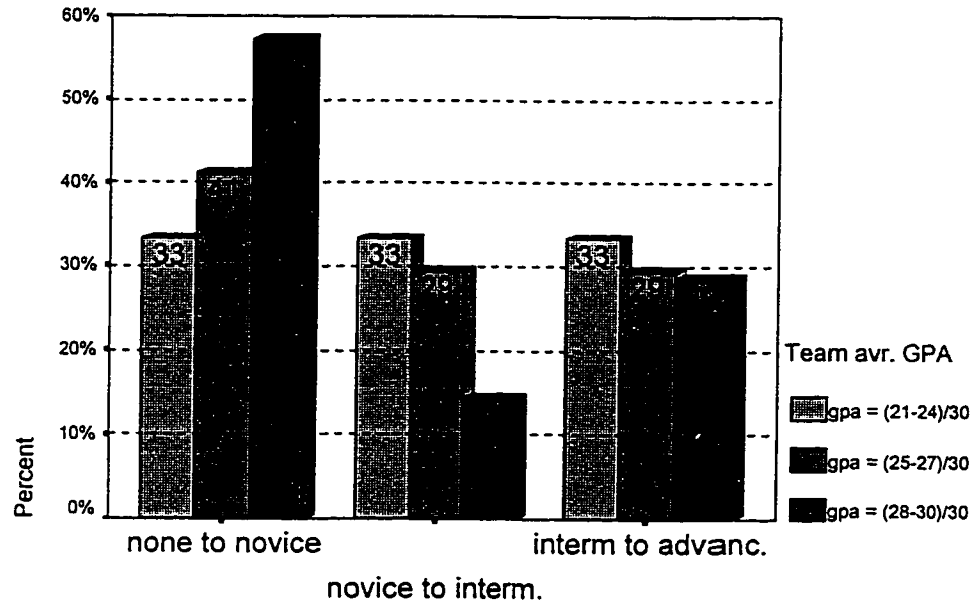


Figure 22. Overall team p.r. competence by average GPA.

4.2 Individual attitudes towards the shared design memory

The data in this section are reported following the three angles of analysis identified in the description of the research model, first at an aggregate level, in terms of the overall community of students, and then taking into account the individual characteristics of the respondents. Concerning the aggregate level, first, data regarding how the different aspects of the pedagogical rationale of the shared design memory were experienced are reported. These are followed by an in-depth analysis of the use made of precedents, as gathered by the answers to the relevant specific and open-ended questions in the questionnaire. Second, data concerning the conceptual and communicative operations involved in sustaining and developing the shared memory are reported. Third, data concerning representational and usability issues of the part of the shared memory embodied in StoryNet are reported.

The first section of Table 2 shows the ratings of the utility of examining precedents, critiquing them and sharing the critiques.

Table 2. Ratings for the utility of examining precedents

	Rating					Missing cases
	very low	low	medium	high	very high	
Utility of examining precedents	-	17.7%	45.2%	32.3%	4.8%	2
Utility of the critique exercise	1.7%	15%	45%	28.3%	10%	4
Utility of sharing the critique	1.6%	4.8%	38.7%	40.3%	14.5%	2

Data in Table 2 consistently report perceptions skewed towards the medium-high end of the scale, indicating a substantial agreement on the key tenets of the rationale underlying the use of StoryNet. There are no particularly revealing differences among frequencies of the responses in the medium category and the sum of the responses in the high-very high categories, except for the utility of sharing the critique, which shows a clear orientation of the responses towards the high-very high categories of the scale, accounting for 54.8% of the cases, versus the 38.7% in the medium category and the 6.4% in the low-very low end of the scale. This result is particularly interesting because, regardless of the perceived utility of actually doing the critique exercise, the students seem to place a very high value on the possibility of looking at the reviews authored by their peers.

In explaining the motivations for the rating of the utility of examining precedents in an open-ended question, the following classes of responses were identified, reported in Table 3 in order of occurrence.

Table 3. Most frequently cited reasons for using design precedents

Use of precedents as:
• Guideline to structure the organization of the project
• Means to detect and avoid errors by comparison
• Bridge from theory to practice, through the exemplification of techniques
• Opportunity to conceptually integrate the contents presented in the course
• Source of new ideas and improvements

All the respondents in the first category (Guideline) were in the none-novice range of p.r. competence. For the cases who rated low the utility of precedents (17.7%), the most frequent motivations for holding such a view were: poor quality of the available precedents, incompleteness, diversity from the theme to be addressed in the new design case.

Although relevant only to a minority of cases, such responses highlight one risk inherent to using a shared memory constructed by the students themselves, that is, unless specific measures are taken, the weaknesses in the novice artifacts might not be for every student a helpful startup point or a playground to exercise critiquing skills. Concerning the seriousness of theme diversity as a hindrance, a mitigating circumstance is the start-up effect of the shared memory. In fact, to start the memory, the students were given the precedents for review by the teaching assistant, based on criteria of availability, if relevance to the new design theme could not be satisfied. Therefore, at the time the responses were collected, there was not enough variety of cases formed in StoryNet to provide more relevant examples.

However, it must be considered that the "official" way of apprehending a precedent was only one of the possibilities used by the students. Concerning the source of the precedents that were examined, 42% of the students resorted to other design cases provided either by colleagues who were authors of such projects (96%) and by colleagues who were not the authors of the design case themselves (30%). The average number of precedents examined individually is M = 2.36 (SD = 1.39, ranging from 0 to 6) and there is no correlation either with level of design experience or with level of overall p.r. competence, or GPA, meaning that although the reasons might differ, everybody was interested in examining the precedents. These figures are indicative of the social phenomenon of exchanges naturally occurring among the students, and raise the questions of whether and in what respect a shared design memory adds to this process.

A more detailed perspective on the perceived effect of examining the precedents, and of re-using part of them comes from the answers reported in Table 4.

Table 4. Responses on the perceived effect of examining design precedents

	Rating							Missing cases
	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree	
Precedents support design rule abstraction	-	1.6%	3.2%	8.1%	37.1%	21.0%	29.0%	2
Precedents support analogy finding	1.6%	6.3%	-	14.3%	27.0%	27.0%	23.0%	1
Relating own design to others foster innovation	-	1.6%	-	11.3%	11.3%	33.9%	41.9%	2
Relating own design to others foster precision	-	5.7%	15.1%	32.1%	24.5%	13.2%	9.4%	1
Precedents reuse aids design	-	3.2%	1.6%	19.4%	30.6	21.0	24.2%	2
Precedents reuse aids comprehension	3.3%	4.9%	1.6%	11.5%	39.3	18.0	21.3%	3

Responses in Table 4 show that there is most consistent agreement with the statement that by relating to precedents one is encouraged to be more innovative, where in this context "innovation" does not distinguish explicitly among the design problem, the design solutions, or the design presentations and representations. This may be indicative of one advantage in having precedents from peers, and not from outside, less questionable "authorities", which could indirectly foster a certain degree of uniformity. Whether this perception concerning innovation actually reverberates in the quality of the design is a question to be tackled in the analysis of the artifacts, presented in the next chapter.

There is marginally more agreement on the statement that precedents support the process of design rule abstraction rather than on the statement that they are vehicles to find analogies, whereas opinions are more varied and more cautious on the issue whether the new designs can benefit in precision by relating to precedents.

Reusing parts of the precedents is generally perceived as an aid to design (75% of the responses in the somewhat agree-strongly agree categories, and 20% in the neutral category). More polarized, with almost 80% of the cases in the agree side of the scale, are the responses on whether the activity of re-using affords particular benefits for a better comprehension, either of the problem or of the design process. Responses to the open-ended question of what were the design elements more easily re-usable were analyzed and coded in the categories shown in table 5, reported in order of decreasing frequency.

Table 5. Design elements indicated as most re-usable

More re-usable elements of precedents
1. Stories and Episodes (mentioned either in general or as instantiated cases, e.g., "warehouse management"
2. System configuration and dimensioning
3. Graphics
4. ERM (Entity Relationship Model)
5. Representations dealing with the dynamic behavior of the system

Concerning the motivations of the rating for the utility of the critique exercise, investigated in an open-ended question, those who expressed a favorable attitude adduced the reasons that appear in Table 6 listed in order of decreasing frequency.

Table 6. Most frequently cited reasons for deeming the critique exercise useful

Reasons for deeming the critique exercise useful
1. A means to avoid errors
2. An opportunity to revise the design
3. A tool for self-evaluation
4. A means to deepen theory understanding

Those who offered explanations for rating low the utility of the critique exercise adduced the same reasons as for the precedents, i.e., low quality of the case and diversity from the application domain with which they were dealing.

The results to this point concerned how the pedagogy inherent to the deployment of the shared memory was received. In the next section, a second angle of analysis examines the conceptual and communicative operations that were implied or requested of the students to use StoryNet, following its design philosophy.

The first section of Table 7 summarizes the agreement level, in a seven point scale, on some statements concerning the conceptual and communicative operations the students were required to perform. The set of questions concerning the links stem from the hypothesis that deploying links entails examining precedents with the aim of finding proper elements for re-use, and that once the design has been carried out, one can still remember what specific aspects of the precedents have exerted influence. This distinction, which might seem unnatural, is due to the fact that in the start-up phase of the memory the actual design cases were viewed outside StoryNet, and then contributed following the story-episode structure described in Chapter 3. It is expected that after the transient start-up phase, this splitting will occur to a lesser extent and that the linking process will support the development and refinement of ontologies in stories and episodes within StoryNet.

Table 7. Responses on the conceptual and communicative activities related to StoryNet

	Rating							Missing cases
	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree	
Links express design reasoning	1.6%	-	3.2%	32.3%	25.8%	22.6	14.5%	2
It is difficult to foresee influences of precedents	1.9%	3.7%	7.4%	40.7%	29.6%	5.6%	11.1%	10
It is difficult to isolate influence of precedents	11.9%	1.9%	11.1%	31.5%	25.9%	14.8%	3.7%	10
Links are useful to peers	-	4.8%	1.6%	19.4%	37.1%	24.2%	12.9%	2
It is difficult to express comments to be useful to peers	15.9%	14.3%	22.2%	17.5%	9.5%	12.7%	7.9%	1
Links are technically difficult to deploy	15.1%	22.6%	13.2%	18.9%	13.2%	11.3%	5.7%	11

The results in Table 7 show substantial agreement with the statements that to deploy links supports the process of articulating the reasoning that went on during design and that such links can be useful to peers. This complements the acceptance of StoryNet's underlying pedagogical tenets. However, the angle of analysis concerning the conceptual operations that are needed to sustain StoryNet reveals a difficulty in the retrospective reasoning that must be performed to articulate what aspects of the current design have been influenced by the precedents (40.7% neutral and 46.3% in the agree side of the scale), and that in the preliminary phase of scanning such precedents it is difficult to anticipate what specific aspects will prove useful in the development of the new project (31.5% neutral and 43.6% in the agree side of the scale). Less difficult is the process of formulating comments in a usable form to peers.

The above difficulties are interesting because whereas there is agreement on the utility of the linking mechanism (response n.1 in Table 7) there is also an indication that it requires an effort that not everybody is apt to sustain, either because of an objective lack of experience that hinders the process of anticipating what might be important, or because there has not been sufficient training in the process of examining the precedents with a comparative attitude. On the other hand, the difficulty of retrospectively tracing what features have been imported in the new design can also be symptomatic of a process of personal internalization and restructuring of the contents and representational formats that have been encountered. This latter explanation is supported by the results reported in Table 6 above, which suggest that the process of examining precedents is done more with the spirit of learning, by finding guidelines or rules and being prompted with new ideas, than with the spirit of re-use, in the conventional software engineering sense.

As for the overall usability of StoryNet, the last response in Table 7 shows that the process of linking cases in the shared memory is not as smooth as it could be, because 30% of the responses agree that there are some technical difficulties in deploying the links. On the other hand, the overall ratings of the ease of navigating and contributing to the StoryNet are quite satisfactory, as shown in Table 8.

Table 8. Responses on the ease of contributing and navigating in StoryNet

	Rating					Missing cases
	very low	low	medium	high	very high	
Ease of navigation in StoryNet	4.8%	11.1%	52.4%	27.0%	4.8%	1
Ease of contributing to StoryNet	4.8%	9.55%	49.2%	30.3%	6.3%	1

Also related to the issue of broad usability and the adequacy of the chosen representational formats for StoryNet, are the opinions about examining in StoryNet different kinds of design representations and the various contributions coming from the participating social actors. Table 9 summarizes the responses on the utility of examining each component of StoryNet, with ratings varying on a three points scale: no utility, little utility, and much utility.

Whereas Table 9 indicates that the supported representations are rated mostly as very useful ("Much utility"), it also shows that the rating of the links is markedly different from the other items, indicating a much more cautious attitude (56.7%) towards the utility of examining the links in StoryNet. This result apparently clashes with the responses in Table 7, in which links are rated as a useful vehicle to express design reasoning. A plausible interpretation at this start-up stage is that, for the first generation of students who deployed the first links, the number of links to actually examine in the system was too low to generate the perception that the mechanism is worthwhile representing and has utility as an additional indexing and navigational mechanism, although it might be effective at the personal level as a device for learning and reflection.

Table 9. Relative perceived utility of the StoryNet representations

	Rating			
	No utility	Little utility	Much utility	Missing cases
Stories	-	27.9%	72.1%	3
Episodes	-	32.8%	67.2%	3
Data Flow Diagrams	9.7%	12.9%	77.4%	2
Entity Relation Model	5%	16.7%	78.3%	4
Peers Comments	6.8%	32.2%	61.0%	4
Instructor Comments	3.3.%	18.0%	78.7%	3
Links	6.7%	56.7%	36.7%	4
Critiques	6.7%	21.7%	71.7%	4

Responses to an open-ended section indicated the following other kinds of information were needed in StoryNet: 1) the dimensioning of the system (most frequent response), 2) entire analysis, 3) the software prototype, 4) other design diagrams, 5) best solutions, 6) the instructor evaluation. Only 36% ventured a response.

The agreement level on statements aiming at capturing the possible roles that StoryNet, as a social and technical system, might perform are summarized in Table 10.

The responses in Table 10 indicate definite agreement that StoryNet is a tool that fosters reflection. Also there is a marked disagreement with the idea that cases in StoryNet should be anonymous. Instead, there is agreement on the idea that the StoryNet could benefit if authors respond to the peer reviews (65% of the cases on the agree side, and 16% neutral). Although StoryNet supports this mechanism, this is unlikely to happen because of the marked asynchronicity with which the groups carry out and complete the design. Indeed, most of the contributions turn up just when the project has been completed, shortly before making the exam. So any after-course volunteering of information is completely discretional. However, it must be noted that in a few cases, some students who had passed the course in June, showed up in the office few months later asking whether they needed some special password to access StoryNet again, because they were curious about the "fate" of their project, if it had generated any comments or critiques.

Table 10. Responses on StoryNet as a social system and as an instrumental tool

	Rating							Missing cases
	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree	
Cases in StoryNet should be anonymous	39.7%	11.0%	3.2%	30.2%	3.2%	1.6%	3.2%	1
StoryNet is more useful if authors respond to critiques	5.6%	3.7%	9.3%	16.7%	22.2%	13.0%	29.6%	10
StoryNet is useful as an index to cases	-	3.2%	1.6%	25.4%	17.5%	31.7%	20.6%	1
StoryNet can be useful without visioning the whole design case	19.0%	12.7%	11.1%	6.3%	20.6%	19.0%	11.1%	1
StoryNet is useful as a reflection aid anyway	-	1.6%	3.2%	9.5%	30.2%	22.2%	33.3%	1

A marked diversity of opinion characterizes the issue whether StoryNet can be useful if the whole design case cannot be accessed, which bears directly on the issue of adequacy of the case representational format. In fact, 42% of the subjects expressed doubts on the utility of StoryNet without apprehending the complete and fully functioning design specification that is presented in Power Point. More considerations on this issue are provided in the section on the relationships between individual characteristics and attitudes towards the shared design memory. In any case, StoryNet was considered useful as an index to potentially useful design cases (70% agreements and 25% neutral).

Before analyzing the relationships between the individual characteristics and the attitudes discussed so far, section 4.3 presents the results of the responses addressing the perceived difficulty of each of the activities involved in producing the design specifications.

4.3 Perceived difficulty and criticality of design activities

In the following, results are reported for individual responses to a set of questions that ask the respondent to express, on a five point scale, the difficulty of a set of tasks related to design. The trends have been also analyzed in relation to specific design experience and GPA.

Table 11 shows that, in general, developing the prototype is considered more difficult than performing the analysis and design (42% rating high against 25% rating high).

Finding a non ambiguous vocabulary to model the system seems the less problematic activity, followed by defining the scope of the project. It must be noted the overall shift towards the "high" difficulty rating in the case of verifying the completeness of the design, and even a more marked shift toward the higher end of the scale in the case of estimating how a change in one part of the design will affect other parts of the system.

None of the above responses was correlated with GPA or p.r. competence, except for estimating how a change in one part of the system propagates. The statistics were computed using the nonparametric Kendall tau_b correlation coefficient (Hildebrand, Laing & Rosenthal, 1977). Estimating the effects of local changes in the overall system was positively correlated with GPA, that is, students with a better average grade tend not to underestimate the inherent difficulty of such activity (Kendall tau_b = .206, p<.05).

Table 11. Perceived difficulty and criticality of design activities

	Rating					Missing cases
	very low	low	medium	high	very high	
Difficulty of overall analysis	-	1.6%	71.9%	25%	1.6%	-
Difficulty of database prototype development	-	1.6%	54.7%	42.2%	1.6%	-
Difficulty of Project scope definition	-	21.9%	54.7%	21.9%	1.6%	-
Difficulty of stories and episodes decomposition	-	10.9%	65.6%	21.9%	1.6%	-
Difficulty of finding non ambiguous vocabulary	-	20.3%	64.1%	12.5%	3.1%	-
Difficulty of verifying design completeness	-	6.3%	31.3%	53.1%	9.4%	-
Difficulty of estimating effects of local changes	-	3.1%	34.4%	46.9%	15.6%	-

The responses to the open-ended question, what was the most critical activity in the analysis for the success of the project, are reported in Figure 23. These were provided by 35% of the respondents. Among the most frequent responses were the definition and structuring of stories and episodes, the specification of the DFD and the ERM and checking the completeness, correcteness and consistency of the specifications.

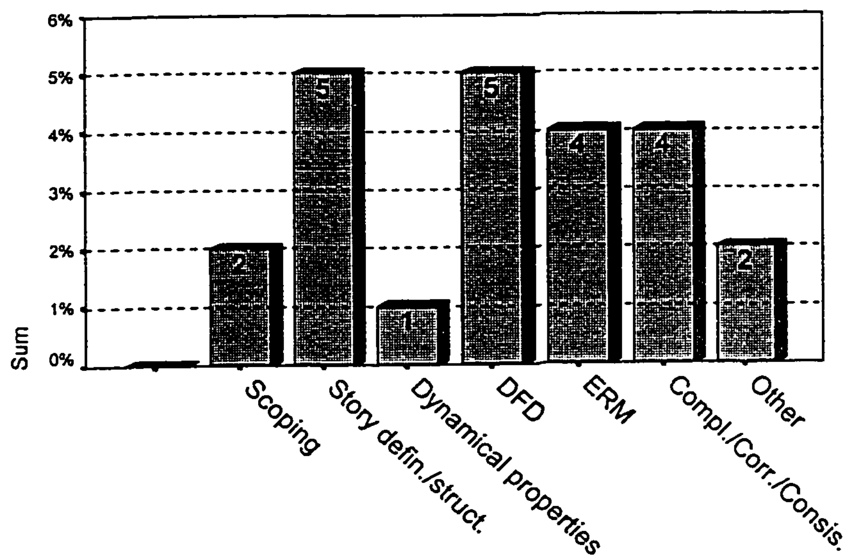


Figure 23. Open-ended responses about the most critical activity for design success

4.4 Relationships among individual characteristics and attitudes towards the shared memory

An exploratory, correlational analysis was performed to investigate the relationships among individual characteristics and attitudes and groups of responses, to highlight, if any, sets of co-occurring attitudes which are interesting either from a theoretical point of view or to understand the factors that are operating beneath the surface of the microcosm realized by the shared memory and the involved social actors.

The statistics are computed, using the nonparametric Kendall tau_b correlation coefficient (Hildebrand, Laing & Rosenthal, 1977), on a sample of 64 cases, using the pairwise selection option for treating cases with missing data. The correlation matrix is reported in Table 12. Because of the large number of variables, the interpretation in the following discussion is mostly based on the significant correlations whose tau_b is larger than 0.30.

Level of individual p.r. competence is negatively correlated with the opinions that critiques are useful as a means to self-evaluation (tau_b = -.338, $p<.05$) and that links are useful means to express design reasoning (tau_b = -.325, $p<.05$). Thus experience seems to be a factor that discounts the utility of doing the critique exercise, almost as if there was not much to gain or to learn. This result is also particularly informative in conjunction with the result on the motivations for giving low ratings, i.e., low quality of the reviewed project, presumably in relation to the quality already achievable by the more experienced students.

The more the design expertise the less precedents are perceived as a means to fostering precision (tau_b = -.299, $p<.05$). Agreements on the statements that precedents support rule abstraction, suggest new aspects for analysis, foster innovation and foster precision are all correlated. In particular, innovation is correlated to precision (tau_b = .601, $p<.05$) and rule abstraction is correlated to suggestion of new aspects to take into account. Agreement on the statement that precedents re-use aids design is positively correlated with perceiving precedents as being suggestive of new aspects (tau_b = .388, $p<.05$) and as fostering innovation (tau_b = .330, $p<.05$).

Correlations

		GPA	Design experience	p.r. competence	prec. constrain design	prec. sugg. aspects	prec. reuse aid design	prec. supp. rule abst.	prec. supp. analogy find.	prec. foster innovation	prec. foster precision	critique usefulness	util. sharing critique	crit. supp. self-eval.	link express des. reas.	links useful. to peers	links depl. techn. diff.	diff. foresee asp. infl.	diff. isol. influen. asp.
Kendall's tau_b	GPA	1.000	.014	.063	.160	.170	.076	.025	.067	.058	-.024	.007	-.023	.084	.022	.065	.089	.145	-.041
	Design experience	.014	1.000	.706**	-.018	.021	-.153	-.041	.019	-.109	-.299**	-.278*	-.165	-.418**	-.261*	-.067	.014	.224	.034
	p.r. competence	.063	.706**	1.000	.079	-.001	-.205	-.070	-.101	-.138	-.224*	-.157	-.093	-.338**	-.325**	-.116	.043	.094	.080
	prec. constrain design	.160	-.018	.079	1.000	.276*	.096	.256*	.102	.069	.012	.224	.294*	-.037	.128	.134	-.171	-.230*	.012
	prec. sugg. aspects	.170	.021	-.001	.276*	1.000	.388**	.421**	.048	.316**	.102	.007	-.028	.155	.188	-.006	-.179	.095	-.032
	prec. reuse aid design	.076	-.153	-.205	.096	.388**	1.000	.270*	.185	.330**	.100	.166	.076	.224*	.227*	.225*	-.227*	-.048	-.286*
	prec. supp. rule abst.	.025	-.041	-.070	.256*	.421**	.270*	1.000	.290**	.389**	.302**	.075	.282*	.100	.147	.078	-.266*	.029	-.302**
	prec. supp. analogy find.	.067	.019	-.101	.102	.048	.185	.290**	1.000	.122	.193	-.149	.041	.094	.105	.154	-.012	.082	.003
	prec. foster innovation	.058	-.109	-.138	.069	.316**	.330**	.389**	.122	1.000	.601**	.182	.212	.290**	.198	.213	-.263*	-.031	-.327**
	prec. foster precision	-.024	-.299**	-.224*	.012	.102	.100	.302**	.193	.601**	1.000	.196	.101	.261*	.282**	.201	-.249*	-.071	-.091
	util. sharing critique	-.023	-.165	-.093	.294*	-.028	.076	.282*	.041	.212	.101	.371**	1.000	.024	.214	.242*	-.137	-.030	-.121
	crit. supp. self-eval.	.084	-.418**	-.338**	-.037	.155	.224*	.100	.094	.290**	.261*	.241*	.024	1.000	.251*	.338**	-.008	.071	-.109
	link express des. reas.	.022	-.261*	-.325**	.128	.188	.227*	.147	.105	.198	.282**	.273*	.214	.251*	1.000	.529**	-.023	.059	-.019
	links useful. to peers	.065	-.067	-.116	.134	-.006	.225*	.078	.154	.213	.201	.171	.242*	.338**	.529**	1.000	-.139	.002	-.010
	links depl. techn. diff.	.089	.014	.043	-.171	-.179	-.227*	-.266*	-.012	-.263*	-.249*	.040	-.137	-.008	-.023	-.139	1.000	.084	.090
	diff. foresee asp. infl.	.145	.224	.094	-.230*	.095	-.048	.029	.082	-.031	-.071	-.029	-.030	.071	.059	.002	.084	1.000	.136
	diff. isol. influen. asp.	-.041	.034	.080	.012	-.032	-.286*	-.302**	.003	-.327**	-.091	-.064	-.121	-.109	-.019	-.010	.090	.136	1.000
	diff. expr. clear com.	.018	-.076	.035	-.020	.173	-.020	.091	-.124	-.011	-.057	.326**	.116	.052	.023	-.094	.201	.072	.125
	authors respons. req.	-.059	.155	.233*	.063	.015	.136	.066	.114	.046	.000	.040	.026	-.022	.001	.145	-.073	.079	.095
	Util. without ent. case	-.145	.131	.156	.347**	-.075	-.005	.230*	-.003	.099	.107	.198	.251*	-.186	.037	.146	-.249*	-.296**	-.147
	reflection aid anyway	.096	-.070	-.130	.151	.105	.188	.277**	.097	.337**	.227*	.208	.311**	.076	.353**	.260*	-.102	-.048	-.288*
	stories usefulness	.175	.165	.102	-.010	.153	-.002	.052	.132	-.042	.055	-.243	-.035	-.035	-.035	-.044	-.197	.187	-.083
	episodes usefulness	.083	.098	.023	.148	.057	-.018	.037	.052	-.016	.016	-.118	.057	.077	-.053	.064	-.189	-.015	-.163
	DFD usefulness	-.070	-.096	-.045	-.097	.044	-.093	.113	.036	.087	.268*	-.057	.179	-.098	.217	.146	-.131	.197	.224
	ERM usefulness	-.054	-.124	-.084	-.038	.024	-.059	.137	.025	.085	.195	-.005	.229	-.127	.316**	.206	-.070	.123	.234
	comments usefulness	-.009	-.014	-.142	.099	-.144	.202	-.188	-.044	.100	-.024	.156	.025	-.028	.031	.110	.044	-.159	-.041
	links usefulness	-.013	-.157	-.266*	-.120	-.106	.088	.203	.041	.201	.108	.040	.308*	.151	.426**	.395**	-.164	.129	-.036
	critique usefulness	.012	-.066	-.045	.262*	-.114	.038	-.029	.015	-.095	-.173	.168	.229	-.114	.082	.107	.040	-.046	.188

** Correlation is significant at the .01 level (2-tailed);
* Correlation is significant at the .05 level (2-tailed); *
N= 64, pairwise selection

Table 12. Correlations among selected individual characteristics and attitudes towards the shared memory

Correlations

		diff. expr. clear com.	authors respons. req.	Util. without ent. case	reflection aid anyway	stories usefulness	episodes usefulness	DFD usefulness	ERM usefulness	comments usefulness	links usefulness	critique usefulness
Kendall's tau_b	GPA	.018	-.059	-.145	.096	.175	.083	-.070	-.054	-.009	-.013	.012
	Design experience	-.076	.155	.131	-.070	.165	.098	-.096	-.124	-.014	-.157	-.066
	p.r. competence	.035	.233*	.156	-.130	.102	.023	-.045	-.084	-.142	-.266*	-.045
	prec. constrain design	-.020	.063	.347**	.151	-.010	.148	-.097	-.038	.099	-.120	.262*
	prec. sugg. aspects	.173	.015	-.075	.105	.153	.057	.044	.024	-.144	-.106	-.114
	prec. reuse aid design	-.020	.136	-.005	.188	-.002	-.018	-.093	-.059	.202	.088	.038
	prec. supp. rule abst.	.091	.066	.230*	.277**	.052	.037	.113	.137	-.188	.203	-.029
	prec. supp. analogy find.	-.124	.114	-.003	.097	.132	.052	.036	.025	-.044	.041	.015
	prec. foster innovation	-.011	.046	.099	.337**	-.042	-.016	.087	.085	.100	.201	-.095
	prec. foster precision	-.057	.000	.107	.227*	.055	.016	.268*	.195	-.024	.108	-.173
	util. sharing critique	.116	.026	.251*	.311**	-.035	.057	.179	.229	.025	.308*	.229
	crit. supp. self-eval.	.052	-.022	-.186	.076	-.035	.077	-.098	-.127	-.026	.151	-.114
	link express des. reas.	.023	.001	.037	.353**	-.035	-.053	.217	.316**	.031	.426**	.082
	links useful. to peers	-.094	.145	.146	.260*	-.044	.064	.146	.206	.110	.395**	.107
	links depl. techn. diff.	.201	-.073	-.249*	-.102	-.197	-.189	-.131	-.070	.044	-.164	.040
	diff. foresee asp. infl.	.072	.079	-.296**	-.048	.187	-.015	.197	.123	-.159	.129	-.046
	diff. isol. influen. asp.	.125	.095	-.147	-.288*	-.083	-.163	.224	.234	-.041	-.036	.188
	diff. expr. clear com.	1.000	.125	-.002	.099	-.218	-.265*	.017	.132	-.244*	-.043	-.173
	authors respons. req.	.125	1.000	.040	.066	-.213	-.272*	.001	-.023	-.039	.084	.060
	Util. without ent. case	-.002	.040	1.000	.281**	-.096	-.024	-.047	-.012	.103	.017	.268*
	reflection aid anyway	.099	.066	.281**	1.000	-.073	-.077	.084	.097	.145	.357**	.089
	stories usefulness	-.218	-.213	-.096	-.073	1.000	.656**	.200	.166	-.184	.009	-.160
	episodes usefulness	-.265*	-.272*	-.024	-.077	.656**	1.000	.138	.187	.004	.050	-.005
	DFD usefulness	.017	.001	-.047	.084	.200	.138	1.000	.882**	-.079	.184	-.055
	ERM usefulness	.132	-.023	-.012	.097	.166	.187	.882**	1.000	-.137	.288*	.073
	comments usefulness	-.244*	-.039	.103	.145	-.184	.004	-.079	-.137	1.000	-.023	.351**
	links usefulness	-.043	.084	.017	.357**	.009	.050	.184	.288*	-.023	1.000	.188
	critique usefulness	-.173	.060	.268*	.089	-.160	-.005	-.055	.073	.351**	.188	1.000

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

N= 64, pairwise selection

Table 12. (Cont.) Correlations among selected individual characteristics and attitudes towards the shared memory

The more precedents are perceived to foster innovation the less the ratings on the difficulty to trace back those aspect in the new design that have been influenced by the precedents (tau_b = -.327, p<.05).

The opinion that the StoryNet is useful also without examining the fully functioning case is correlated with the opinion that precedents provide rules that constrain the new design (tau_b = .347, p<.05). Because this response helps us understand the issues of the adequacy of case representation in StoryNet, it is worth considering also the significant correlations with a value of tau_b slightly less than 0.30. Those who project a more favorable attitude towards StoryNet even without examining the full functioning case are more inclined to value precedents to abstract general design rules (tau_b = .230, p<.05), to encounter less technical difficulty in deploying the links (tau_b = -.249, p<.05), and have less difficulty in foreseeing the application of what they examine to their own problem (tau_b = -.296, p<.05).

The results above suggests that the core representational solution adopted for StoryNet, i.e., the story-episode architecture, augmented by the DFD and ERM diagrams and the links, which emphasizes structure over the animation of the dynamics afforded by the fully functioning design precedent, favors, or rather is more easily apprehendable by those who are inclined to abstract rules from precedents, or by those who find it technically easy to use the system and encounter less initial difficulties.

Agreement on the statement that StoryNet is useful as a reflection aid anyway is positively correlated with three different kinds of perceptions : 1) that links express design reasoning (tau_b = .353, p<.05); 2) that examining precedents fosters innovation

($tau\_b = -.337$, $p<.05$); and 3) that it is useful to share the design critiques ($tau\_b = .311$, $p<.05$).

Ratings for finding most useful in StoryNet the graphical or diagrammatic representations, i.e., Data Flow Diagrams and Entity Relationships Models, are correlated ($tau\_b = .882$, $p<.05$), however preference for each of these representations tends to be associated with a different response. In fact, higher ratings for the DFD are associated with the perception of precedents as fostering precision ($tau\_b = .268$, $p<.05$), whereas higher ratings for the ERM are associated with higher ratings of the utility of examining links ($tau\_b = .288$, $p<.05$) and that links are useful to express design reasoning ($tau\_b = .316$, $p<.05$). These latter indications can be interpreted by taking into account the different nature of these representations. Because the linking mechanism favors the evolutionary creation of increasingly refined task ontologies related to the use-cases of the information system (Faro & Giordano, 1997b) and the ERM has a strong semantic and static connotation that condenses the underlying design reasoning, it might be easier to trace the evolution and changes in an ERM diagram rather than in a DFD. Thus those who are more comfortable in dealing with this kind of representation are probably more likely to have less difficulty in projecting the network of links across design cases.

It must be recalled that this set of responses are the counterpart to those more focused on the process of carrying out the design activities and producing the relevant representations. This counterpart focuses just on examing the final outcome. as an excerpt of a worked out example. This consideration makes more understandable the association between the utility of examining links and deeming them useful to express design reasoning ($tau\_b = .426$, $p<.05$).

4.5 Summary

The above discussed responses and set of correlations, taken together, offer a more in-depth view of the social and cognitive factors that operate in the background of StoryNet.

The first striking result is the diversity of the motivations and ways of approaching the use of precedents, and the additional representations gravitating around them. All of these concur with the overall acceptance of the system from the students. The precedents are not used only for analogical reasoning aimed at the re-use of stories and episodes specifications. To this extent it must be noted that in setting up the conditions for StoryNet, on purpose, no specific or constraining directives on how to use the precedents were given, other than those that are implied by the requirement of representing in StoryNet the influence links, whatever they would be, and the critique. It was clearly stated that the major emphasis of the course was on the final design outcome, and that the critique exercise was meant as instrumental to increasing the quality of such outcomes. The limits placed on the re-using of elements, if re-use was deemed appropriate by the design team, as discussed in section 3.2, concerned more the requirements of making apparent the original (i.e., personal) elements of the contribution. Thus it is unlikely that such a "limit" on re-use has biased the students' perceptions of how precedents had to be approached or how they were useful, also because the number and kind of links that were deployed (see next section) indicated a percentage of re-use and adaptation of precedents elements far less than the threshold of 50% recommended by the instructors. Although the links might suggest that re-use happens only to a limited extent, the responses coming from the questionnaire provide a more complete account of the type of re-use that takes place. In fact, precedents are used also to a great extent as exemplificatory devices from which rules about structure and organization of the design, especially concerning the stories and episodes decomposition, are derived, and as a baseline against which the quality standards achievable or to be achieved in the new design are set. In this respect the critique exercise plays a supporting role, being perceived as a useful means to learn to recognize and avoid errors, with the exception of those who have more design experience, who tend to discount its utility, especially in conjunction with the fact that a precedent might be low quality or addressing a theme which is not relevant to their design.

Another interesting source of variety is the different appeal that various types of representation have at the individual level. These are reflected at least in two broad areas of interests. One revolves around narrative and social modalities of discourse, with interest in apprehending the stories and episodes as a first attack on the design problem, and in the comments and critiques generated around them, mainly to integrate domain knowledge. The other is more focused on apprehending the classic, more graphic representations of design, DFDs and ERMs, in a mode of discourse that is perceived to better accommodate issues of precision and of explicit expression of design reasoning through the links.

This picture is still to be completed by the analysis of the actual contents of the StoryNet and of the actual quality of the produced artifacts.

4.6 Content analysis of the critique exercise

The reviews produced by the teams were analyzed by classifying each critique statement as belonging to one of the following problem areas :

a) *Dynamics*: concerns the dynamical and simulation aspects of the domain analyzed, and the correct use of the appropriate modeling techniques;

b) *Breakdowns*: concerns the anticipation of possible breakdowns in the normal functioning of the system and devising exception handling procedures;

c) *Problem scoping*: concerns the definition of the problem boundaries;

d) *Structuring*: concerns issues of decomposition and organization, and includes the appropriate use of generalized structures;

e) *Language*: concerns the specificity or ambiguity of the language used;

f) *Domain accuracy*: concerns the accuracy of the description of the domain, including the omission of major defining features;

g) *Design discourse*: concerns all the aspects of data modeling and methodology application;

h) *Communication*: concerns all the aspects involved in the effective communication of the analysis and design representation, from the graphical layout to the explanatory comments to the design representations.

A total of 32 reviews were analyzed and classified by the researcher, yielding the distribution of statements concerning weaknesses detected by the reviewers shown in Figure 24. To interpret the distribution it must be taken into account that each review might contain more than one statement for each type of weakness.

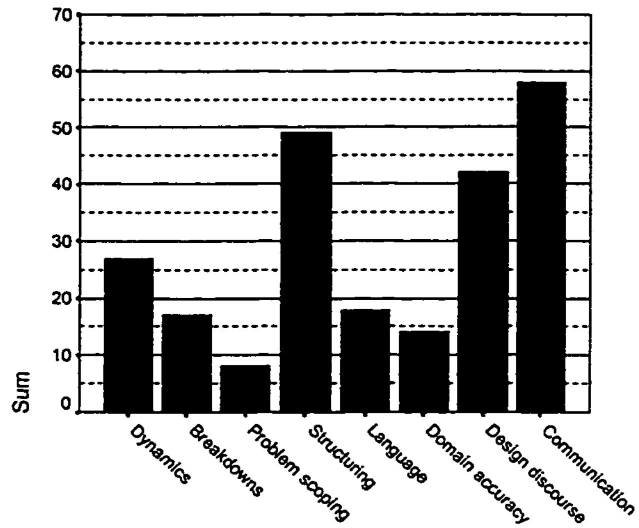


Figure 24. Distribution of the type of weaknesses highlighted in the reviews of precedents.

For the purposes of the present analysis, it can be remarked that the distribution shown in the graph must not be interpreted as representing the average quality of the reviewed precedents. Rather it is a representation of what was perceived by the students at their current level of maturation, given the "observation lens" of the critique guidelines, the particular precedent examined, and their expressive ability. In fact, the most frequent comments in a problem area could be accounted for partly by a better sensibility of the reviewers towards the underlying issues. Thus the distribution is better interpreted as meaning that the overall system, socially, was able to find instances of issues to be aware of occurring in the whole spectrum of problem areas, certainly with a varying degree of penetrating insight, but demonstrating that there was no "organizational blindness" to any if them.

Each review was also coded as to whether it was effective in highlighting the strengths and weaknesses of the precedent, by meeting the criteria of clarity of expression and localization, i.e., justification by direct reference to an easily identifiable part of the precedent itself, or by communicating domain or design knowledge. A statement was considered as conveying domain knowledge when the authors justified their evaluation by making explicit reference to the application domain, and as conveying design knowledge when the authors justified their evaluation by proposing solutions, or by introducing a new aspect that was not suggested in the review guidelines.

Approximately half of the contributors (i.e., 15 teams and/or individuals) were able to communicate effectively the strengths and weaknesses of the reviewed cases, and approximately 40% did so by referring to the domain application.

A similar pattern occurs for the links among the design cases. Of the overall contributing teams or individuals, 85% placed links to the precedents. The average number of links placed was 2, ranging from 1 to a maximum of 4. The majority of the links were of the type "Adapt" (24%), "Use partially" (18%), and "Other" (18%). However, the links that cogently expressed design reasoning other than the synthetic type were only 32% of the total.

The figures of 40% of the reviews and approximately 30% of the links conveying knowledge are important to estimate the potential of the shared memory for highlighting weaknesses and strengths in context; and potential impact, when the number of cases increase, of the contents of the shared memory, and the added information gain with respect to the knowledge implicitly conveyed by the case representation itself.

Whether the highlighted weaknesses tend to disappear, as a form of organizational learning, and, conversely, whether the highlighted strengths tend to be absorbed and re-purposed, is one question that can be pursued according to two strategies. One strategy is to check whether, for any specific team, the sort of issues that they were able to perceive are absent or re-purposed in their own design. This would require a point-by-point cross-analysis of the reviews and the design artifact that is outside the scope of this study. Also, this sort of micro analysis would not necessarily be insightful for the purpose of understanding the global effects of the shared design memory. The second strategy is to conduct an aggregated analysis addressing whether, among the classes of weaknesses highlighted in the reviews, there is any that tend to be less frequent in the new generation, compared to the former one, using as a reference point an independentent evaluation of both the reviewed precedents and the newly produced cases, and then comparing the result with the distribution of the critique contents, to highlight matchings and discrepancies. This qualitative comparison can help to better characterize the effects of the shared critique as mechanism supportive of organizational learning, beyond the impact on reflection and self-evaluation that was highlighted by the students in their responses to the questionnaire. This is the strategy that is followed, and thus an answer to this question is indirectly derived as a byproduct of the analysis of the design changes across generations, to follow in Chapter 6.

The next chapter is devoted to the theoretical and methodological issues involved in defining design quality and describes the instrument used to measure it and compare the various generations of designs.

Chapter 5

Evaluating design quality

One fundamental difference between the empirical studies of analysis and design typically found in the literature and the present study is that the analysis and design task is not one assigned by the experimenter and carried out under controlled conditions. On the contrary, the spirit of the study is to focus on the design artifacts as produced in a social setting, and to look at them in their entirety, rather than as dissected in small components which are the products of a very specific activity, such as modeling the requirements with a specific formalism (Batra & Davies, 1992) or requirements validation (Kim & March, 1995) or definition of the software architecture of modules in the system (Rehder, Pennington & Lee, 1997). This has an impact on the framework to adopt to compare the quality of the designs. In fact, in the studies just cited, the main approach used to deal with quality is to compare the design generated by the subjects with the solution generated by one or more experts, and to score either with respect to completeness or with respect to specific kinds of errors that might occur in the given experimental task. On the other hand, for the purposes of the present study it is necessary to find a reference framework to deal with projects that tackle vastly different application domains, and this takes into account the circumstance that, because of the richness and variety of the representations used, certain weaknesses are less serious than they might appear if they were considered out of context. Thus the first section of this chapter critically examines the notions of quality in the conceptual models and in the data models and explains the foundations for the scoring template developed to evaluate the designs. The second section illustrates the design scoring template, which is based on a set of elementary design features mapped onto a set of quality dimensions, and the third section details the criteria for judging the design features which need a score other than present or absent.

5.1 Quality in conceptual models and in data models

Although there are some "intrinsic" qualities of the conceptual model as a representation, such as its syntactic correctness or its readability, these can be considered of secondary importance compared with the issue that the semantics of the models are correct and complete with respect to the domain and the activities that the information system is supposed to support. In a recent framework for quality in conceptual models (Lindland, Sindre & Solveberg, 1994) it is proposed that *syntactic* quality, *semantic* quality, and *pragmatic* quality (i.e., that the model is understood by the interested parties) must be addressed in terms of a *feasibility* goal, because total validity and completeness, defined, respectively, as the property that all statements made by the model are correct and relevant to the problem, and as the property that the model contains all the statements about the domain that are correct and relevant, cannot be achieved except for very simple problems. Thus the goals of semantic quality are *feasible validity* and *feasible completeness* of the model, and the goals of pragmatic quality are *feasible comprehension* of the model. Quality properties of the model often referred to in the literature, such as correct, minimal, annotated and traceable, consistent, and unambiguous are mostly subsumed by validity and completeness.

The insight in the notion of feasibility is the consideration that total validity and completeness cannot be achieved except for very simple problems and that, once the model starts being built, it becomes part of the domain, and the extent to which validity and completeness can be relaxed depends on the "audience" of the model, for example on the competence of the analysts, end-users, domain experts, and other stakeholders. Thus feasibility provides a stopping rule to terminate the modeling activity, i.e., it defines when the model has reached a state where further modeling is less beneficial than applying the model in its current state. In this framework, a model is feasibly valid if the additional benefits of removing any invalid statement from the model do not exceed the drawbacks of including it, and it is feasibly complete if the additional benefits of including the set of correct and relevant statements not yet in the model do not exceed the drawbacks of leaving them out. The same kind of reasoning applies to pragmatic quality, which focuses on the goal that the model is understood by the interested parties, rather than on the abstract property of "comprehendability". Means to achieve this goal are on the one hand, ensuring that the model has the properties of executability, expressive economy and structuredness, and on the other hand, engaging in the modeling activities such as inspection, visualization, animation, explanation and simulation.

An approach specifically focused on the quality of the data generated by an information system is proposed by Wand and Wang (1996). While pointing out that there does not exist a rigorously defined or established set of data quality dimensions, even for relatively intuitive concepts such as accuracy, and that in any case data or information quality depends on the actual use of data, they call for a design-oriented definition of data quality that reflects the intended use of the information. Because quality of information is related to how data are used, quality of the data generated by the information system should not be couched in terms of "data centric" concepts such as entities, attributes and values, but in relation to intrinsic dimensions, assuming that the true intentions of the users have been captured in the conceptual model. Such intrinsic dimensions are: 1) *Complete* (there is no loss of information about the application domain), 2) *Unambiguous* (data generated by the information system cannot be interpreted in more than one way), 3) *Meaningful* (data can always be interpreted in a meaningful way), and 4) *Correct* (data derived from the information system conform to those used to create these data).

This view complements the notion of feasible quality in the conceptual model by emphasizing the mapping process from the requirements to data, in such a way as to orient the data model towards the consequences in the prototyped information system, with the warning about the different meaning that terms such as correctness and consistency assume in the two described frameworks. In the latter one, they are used in a narrower context, referring specifically to the generated data, and correctness is linked to a problem of implementation and operation of the information system, rather than design (internal view of the information system). Whereas the sharp distinction between the external and internal view can be criticized, both on epistemological grounds and also in the light of the pragmatic view presented in the conceptual modeling framework, it is clear that there is something to gain by injecting in the conceptual modeling framework more concreteness regarding the specific aspect of data modeling, as an explicit link to the design aspects.

However, an important but overlooked dimension is how, in the traditional approach to quality, the conceptual and data model that are being crafted handle issues of *interactivity* of the overall system, also considering that within a scenario-based approach to design, such as STT, the interaction between the users and the system is not a separate aspect of the design of the data. A way to address this aspect of quality is to place emphasis also on the modeling of the dynamic interactions in the system, resorting to different representations to carry through the design the user and his or her interactions with the data. This kind of modeling effort is beneficial as an exercise to learn about interactions and user-centered design. It is also beneficial for the consistency of the data.

The above considerations imply that feasible completeness and feasible validity of the conceptual model have to be evaluated also in the light of the produced software prototype. As it has been observed during the exams, some of the conceptual models that could have been indicted on grounds of incompleteness or underspecification of the data model with respect to the sketched stories and episodes, bridge those gaps competently in the software prototype. However, this tendency, which is quite understandable given that in the context of this study analysts and implementors coincide, is counterbalanced by the awareness that the model has to be understood by the instructors and critiqued, very often by playing the role of the end-users, during the oral discussion of the exam.

A consequence is that, for the purpose of the study, completeness of the model is not the most powerful indicator of the quality that we are seeking in the models. Neither is syntactic quality, and, in any event, studies of novice biases do not point to this aspect as a particularly problematic one. Rather, one must bear in mind that, for the subjects of this study, definition of what the requirements are is an essential part of the exercise, not simply the mapping process from the requirements to data. Many emergent qualities of the design can be traced to the insightfulness with which the salient aspects of the domain are captured. It is evident, then, how completeness is first relative to the slice of the universe that has been identified as of interest, and that a huge part of the effort is invested in understanding how to perceive that domain in relation to the design goals.

5.2 A feature-based approach to characterize design quality

The framework adopted for evaluating the design quality is centered on the following points:

- Semantic quality of the overall conceptual model, especially focused on feasible validity;
- Emphasis on completeness meant as multidimensionality of analysis relative to the stories/episodes identified by the students, which set the internal standard for evaluating the design;
- Feasible completeness and validity of data modeling, relaxed with respect to the fact that small errors cease to assume relevance if they are corrected or disambiguated in further representations, and often complemented by the implemented prototype;
- Integration of a dimension that explicitly takes into account interactivity;
- Communication, to address feasible pragmatic quality of the design.

Accordingly, the design scoring template has been developed following a design features approach, i.e., grading 0 or 1 either the absence or presence of a certain design feature, mostly concerning representational and/or stylistic solutions, and a graded quality evaluation for some of the dimensions of domain modeling specificity and data modeling (0.5 if a minor weakness is present, 0 if a major weakness is present and 1 for feasible validity).

The feature-based approach is particularly appropriate in our case because, whereas in other studies the designs are comparable because they deal with the same problem, in this context it is necessary to find a common reference point across designs that tackle different problems. Also, a feature-based analysis is a more effective way to detect, from an organizational learning point of view, what tends to become consolidated. what is emerging or tends to disappear generation after generation.

The set of features and their values have been mapped to contribute to the definition of the values of the following quality indicators:

- *Domain modeling specificity*
- *Structuring (decomposition)*
- *Structuring (composition).*
- *Data modeling*
- *Dynamics of interactions*
- *Breakdown*
- *Communication*
    - *Textual communication*
    - *Visual/hypertextual communication*

The list of features that form the indicators and the range of variation of the scores is reported in Table 13.

The novice difficulties and biases mentioned in Chapter 2 are mapped onto the above dimensions as follows. "*Domain modeling specificity*" is an indicator of the specificity of the language, derived from the ratios of domain specific entities to total entities, domain specific functions to total functions, and domain specific interactions to total interactions. "*Breakdown*" addresses depth of analysis and indirectly indicates the ability to generate testing scenarios against which to evaluate the quality of the data model. "*Structuring (decomposition)*" aggregates the design features that indicate an effort towards organizing the decomposition of the static and dynamic data models following the story/episode model, or the top-down approach, or both; or an effort to organize the entities by using, for example, "consist of" structures. "*Structuring (composition)*" aggregates the design features that indicate an effort towards maintaining, in a global representation explicit information about the elements that are aggregated and composed, either by color-coding or with links, or by simulating through animation the incremental creation of the global representation.

Table 13 indicates the range of variation of the scores for each dimension. It must be noted that for the ranges highlighted with the asterisk, namely, Structuring (decomposition), Structuring (composition), and Communication (visual-hypertextual), the maximun value is a theoretical one, i.e., in practice, the number of features that co-occur in the best cases are from one to two points lower than the theoretical maximum.

In the template those features corresponding to design representations required by the methodology and those that are so diffused that they are present in any project are not included (for example, the entity-life history, or optimization of the dimensioning of the system). Also, features that only add to the visual readability of the project, such as labels in the arcs, are not considered, because no specific communication content is associated with them.

Table 13. Features contributing to design quality indicators and range of variation of the scores.

Domain modeling specificity	Structuring (decomposition)	Structuring (composition)
range : 0-4	range: 0-8 *	range : 0-6 *
• Ratio of domain specific entities to total entities • Ratio of domain specific functions to total functions • Ratio of domain specific interactions to total interactions • Use of organization charts	• Use of "consist of" structures • ELH associated to the episodes • PO associated to the episodes • DFD structured by episodes • ERM structured by episodes • Prevalence of representations of actors vs. functions • Use of story/entity matrix • Top-down decomposition of episodes	• Use of colored arcs in the DFD to identify stories/episodes • Use of colored functions in the DFD to identify stories/episodes • Link from ELH to episodes • Link from ERM to episodes • Diagrams obtained as incremental block composition • Top-down DFD within episodes
Data modeling	**Dynamics of interactions**	**Breakdown**
range : 0-11	range : 0-6	range : 0-2
• Analysis by aspects • Use of "consist of" structures • Datastores correctness • From entities to relational tables transformation • Relational tables partitioned by stories • ERM correctness • Relationships correctness • Use of "is a" structures • Ternary relationships • Normalization • Normalization correctness	• Animated ELH • Episodes tree • Animated episode tree • DFD animated in synchronization with the episode • Animated Petri networks • Petri Networks with animated captions	• Insightful What Can Go Wrong • What Can Go Wrong represented in the episode tree
Communication (textual)	**Communication (visual-hypertextual)**	**Index of design Complexity**
range : 0-5	range : 0-12 *	
• Commented matrixes • Introduction to the methodological approach • Introduction to the domain • Description of high level scenarios and use cases • Commented organization charts	• Iconic diagram boxes • Iconic arcs • Use of colored arcs in the DFD to identify stories/episodes • Use of colored functions in the DFD to identify stories/episodes • Loose animation: PN presented in blocks • animated entities in ERM • "Live" entities • "Live" relationships • "Live" arcs • Animated normalization • Petri Nets with animated captions • Animated Petri nets • DFD animated in synchronization with the episode	• Computed as the sum of the following: • N. of stories • N. of episodes • N. of functions • N. of entities • N. of interactions in the DFD • N. of entities and relationships in the global ERM • Max (states and arcs in the ELH) • Max (transitions, places in the Petri Nets) • Max (arcs and states in the automata)

Note: ELH = Entity Life History; PO = Process Outline; DFD = Data flow Diagram; ERM = Entity Relationship Model

An index of complexity of the project is also computed by simply counting and adding the following items: number of stories, episodes, functions, entities, and interactions in the DFD, the maximum of the sum of states and arcs in each ELH, the maximum of the sum of transitions and places in each Petri Network, the maximum of the sum of arcs and states in each automaton, and the sum of entities and relationships in the global ERM. With this method, both the static and dynamic dimensions weigh in a balanced way.

5.3 Judgment criteria for the graded features

In the following the judgment criteria for major and minor weaknesses used for scoring the graded features are elaborated. For example, ERM = 0 means that the entity relationship diagram is either absent or has some major weaknesses, ERM = 0.5 means that the entity relationship model is present and has some minor weaknesses whereas ERM = 1 means that it is feasibly valid.

ERM correctness

Major weaknesses: Confounding entities with processes and omitting entities that are suggested as crucial in the stories/episodes.

Minor weaknesses: Syntactic errors or sparingly present ambiguities; confounding entities with processes (but corrected in the normalization).

Relationships correctness

Major weaknesses: Omitting a relationship that is suggested as crucial in the stories/episodes; relationship is represented by a process.

Minor weaknesses: Syntactic errors; omitting the cardinality of the relationship; relationship is represented by a process but is eliminated in the normalization.

Datastore correctness

Major weakness: Absence of the data stores-entities cross-reference (implies carelessness or too a simplistic model).

Minor weakness: All the entities correspond to datastores, absence of any aggregative form.

Normalization correctness

Major weakness: Normalization procedure applied incorrectly

Minor weakness: Absence of motivation as to why normalization has not been carried out completely.

Insightful What Can Go Wrong

Major weakness: The majority of the WCGW identified are trivial, i.e., would generally hold for domains or problems other the one being analyzed, for example "the store is closed" or the terminal is broken. The identified handling procedures basically suspend activity until the problem is solved.

Minor Weaknesses: The above situation holds only for one or few cases, the wcgw adds to the domain knowledge, but the proposed handling procedure is questionable.

Overall Domain modeling specificity

In this case accuracy is related to the specificity of the language. There is no direct grading scheme, rather the indicator is derived from the ratios of domain specific entities to total entities, domain specific functions to total functions, and domain specific interactions to total interactions. Each of these ratios is scored 0 if it is less than 30%, 0.5 if the ratio is between 30% and 70% and 1 if the ratio is higher than 70%.

Plus, one point is added for the presence of an organizational chart-like feature that conveys knowledge to interpret the other representations. Thus the overall range for Domain modeling specificity is 0-4.

After having laid down the schema and the criteria for evaluating the aspects involved in design quality, the context is set for Chapter 6, which illustrates the methodology and the results of the analysis of the design changes across generations.

Chapter 6

Design Changes Across Generations

This chapter starts by describing, in Section 6.1, the method used to conduct the generational analysis of the designs, and then proceeds to illustrate and discuss incrementally the results. Section 6.2 qualitatively discusses the variations in each of the design quality dimension across the three generations, for a first high-level characterization of the changes. A detailed analysis of the 2nd and 3rd generations follows, based on the correlations within each generation of the various dimensions of design quality. This is the object of Section 6.3 and Section 6.4. Then Section 6.4 illustrates the phenomenon of transferring representational modes across generations, which is part of the organizational learning that is taking place. Finally, Section 6.5 presents three small case studies of outliers in the 2nd and 3rd generations, which exemplify both the leverage and the risks that are counterparts to the shared memory.

6.1 Method

To evaluate the trend of design quality a random sample of 16 projects was drawn from the pool of 34 cases belonging to the new generation (from now on, referred to as the 2nd generation) and a matching set was created by selecting the corresponding reviewed projects from the old generation (from now on, referred to as 1st generation). Because one of the reviewed precedents was missing and two cases of the sampled 2nd generation had reviewed the same precedent, the matching set was completed by adding two other cases drawn from the pool of precedents available to the students.

An additional 16 cases were sampled from the pool of the 3rd generation cases, i.e., the projects of the teams who presented themselves for the exam in the time span from September to November 1997, with the aim to compare their quality to that attained by the 1st and the 2nd generation and further characterize the dynamics of the organizational learning process.

The projects were scored blindly by an independent rater, an expert in the field, following the template elaborated in the previous chapter. No formal inter-rater reliability coefficient was generated. However, the scoring method is quite "objective". Of the 55 features considered in the scoring template, 49 are categorical (feature present or not). Only six features are graded. The researcher checked a number of cases (20%) to confirm agreement regarding scoring and found no variation. During the scoring activity, the expert consulted with the researcher whenever a dubious case arose (typically regarding the six graded features) and scoring was based on consensus. This process was blind for the researcher also.

Data from the three generations were screened separately for outliers and plotted for a qualitative analysis of variations in their distributions. Outliers were analyzed as small case studies by resorting to all the information available, in the attempt to explain the reasons underlying their singular strengths or weaknesses, and also to evaluate whether they had to be excluded from the sample for the subsequent analysis. The characteristics of outliers in the higher end of the scale in the first generation suggested specific aspects to trace in the next generations to register any tendency of the outlying values to be assimilated to the norm.

A correlational analysis using the Spearman ρ rank correlation coefficient was performed to investigate the relationships among the various dimensions of the design quality for second and third generation, taking into account the characteristics of the teams, i.e., team average GPA, team overall previous related (p.r.) competence, and whether any of the team members had personal experience in the domain chosen for the project. Because of the relatively small sample size (16 cases) with respect to the number of dimensions to examine, for the correlation matrix in each generation Bartlett's sphericity test was performed to test the hypothesis that the correlations in the correlation matrix are zero. The sphericity test was performed after transforming those individual design dimensions that were not already normally distributed. Subsequently, the approach followed in the analysis was to revert, for convenience of interpretation, to the nonparametric correlation matrices (in which the variables were not transformed). This step was performed after verifying that the significant nonparametric correlations (Spearman ρ) addressed in the interpretation were consistent with those (Pearson r) found in the matrix for which the sphericity test was significant.

Finally, a correlational analysis for elementary design features and generations was performed to highlight, at a micro level, what were the practices, or representational modes starting to become diffused in the new generation.

The fact that no information was available about the teams of the 1st generation projects to establish the equivalence of generations was considered a non-issue with respect to the overall aim of the analysis on the following grounds:

- The aim of this exploratory analysis is not to establish whether two equivalent groups perform differently due the fact that one has worked under the conditions created for the shared design memory. Rather the intent is to establish how a shared design memory affects the process of knowledge transfer across and within generations. In this respect it is not important who produced the designs of the first generation as much as it is important that they are representative of the quality that was attained in the former year and that there is no bias in the selection, with the possible exception of sampling error. Also, the overall quality of the cases that are being compared is such that the exam was successfully passed, and the variations are mostly due to weaknesses rather than serious mistakes, as discussed in the section on novice biases, or to some remarkable insight for the most successful ones. This sort of pre-screening for the pool of projects that was made available initially was done at the beginning, by excluding from official circulation all the seriously flawed cases, those that at the exam got marks less than 25/30. However, these cases are not representative, being less than 15% and typically being the outcome of students who decide to prepare the exam very hastily, as one last resort to meet the official university requirement in the number of sustained courses for registering regularly in the next academic year. No filtering was performed on the projects that gradually were contributed to StoryNet from June to November by all the individuals or teams that passed the course.

- There is no reason to suspect any systematic change from the last years in the populations of students that enroll in the course.

6.2 High-level changes in design quality across generations

The descriptive statistics for each aspect of the design quality for the three generations are presented in Table 14. The relevant boxplots are in Appendix C. The individual distributions are discussed in the following based on the analysis of the stem and leafs plots. The stem and leaf plot provides a concise representation of the distribution of the scores by representing explicitly their digits and their extreme values. Digits are split into a "stem" and a leaf. The "stem" of the plot represents the first digits or group of digits of the scores falling within an interval (stem width) that is computed to reflect the actual distribution of the scores. Each leaf can represent one or more cases with the same remainder in the score.

Table 14. Descriptive statistics for aspects of design quality for the three generations

	Generation	Mean	Median	Std. Deviation	Minimum	Maximum	Skewness
Domain modeling specificity	1st Generation	2.63	3.00	1.02	.00	4.00	-1.66
	2nd Generation	3.41	3.00	.55	2.50	4.00	.08
	3rd Generation	2.80	3.00	.94	1.50	4.00	-.07
Structuring (Decomposition)	1st Generation	2.75	2.00	1.45	1.00	6.00	.95
	2nd Generation	3.97	4.00	2.16	1.00	7.00	.13
	3rd Generation	3.60	3.00	1.54	2.00	6.50	.77
Structuring (Composition)	1st Generation	2.19	2.00	1.52	.00	6.00	.82
	2nd Generation	2.00	2.00	1.15	.00	4.00	-.30
	3rd Generation	2.23	2.00	1.03	1.00	4.00	.45
Data Modeling	1st Generation	5.28	5.00	1.61	1.50	8.00	-.57
	2nd Generation	5.34	5.25	2.58	.00	9.00	-.18
	3rd Generation	5.80	5.50	1.60	3.50	10.00	1.07
Dynamics of interactions	1st Generation	1.06	1.00	.57	.00	2.00	.03
	2nd Generation	2.25	2.00	1.06	.00	5.00	.57
	3rd Generation	3.07	3.00	1.33	.00	5.00	-.55
Breakdown	1st Generation	1.53	1.75	.56	.50	2.00	-.78
	2nd Generation	1.38	1.75	.74	.00	2.00	-.63
	3rd Generation	1.50	1.50	.53	.50	2.00	-.81
Textual communication	1st Generation	1.44	1.00	.63	1.00	3.00	1.18
	2nd Generation	2.44	2.50	.79	1.00	4.00	-.23
	3rd Generation	2.30	2.50	1.31	.50	4.50	-.02
Hypertextual communication	1st Generation	1.94	2.00	1.22	.00	4.00	.04
	2nd Generation	3.63	3.50	1.71	1.00	7.00	.22
	3rd Generation	4.17	4.00	1.60	1.00	7.00	-.15
Complexity	1st Generation	121.56	107.00	36.01	79.00	201.00	1.06
	2nd Generation	121.41	123.50	34.02	61.00	185.00	.03
	3rd Generation	124.63	121.00	35.16	82.50	197.00	.66

Concerning *Domain modeling specificity*, the distribution for the 1st generation, detailed in the stem and leaf plot of Figure 25, is not surprising (12 cases scored 3 and only one case scored 4), given that this dimension reflects the bias of lack of specificity or "stereotyping" frequently observed in the precedents. The situation is markedly better in the 2nd generation, in which the lowest value is 2.50 and the distribution is skewed towards the highest value, i.e., 4, with 15 out of 16 cases falling between 3 and 4.

The 3rd generation is more balanced, reflecting an intermediate situation, with ten cases in the range 3-4. It is slightly skewed towards the lowest value, which is 1.5.

```
Domain Modeling Specificity

1st Generation           2nd Generation            3rd Generation

Stem &  Leaf

0 | 0                    0 |                       0 |
1 | 00                   1 |                       1 | 555
2 |                      2 | 5                     2 | 00
3 | 000000000000         3 | 00000000              3 | 000000
4 | 0                    4 | 0000000               4 | 0000
```

Figure 25. Stem and leaf plot for *Domain modeling specificity*.

Structuring (decomposition) reveals a marked effect for the second generation, regarding the increase in the structuredness of the design (Figure 26). Its symmetrical distribution is such that the value 6, which was an outlier in the 1st generation, is now at boundaries within which fall 50% of the cases in the 2nd generation. This indicates that some of the features, or different combinations of features relative to modes of organizing and layering the design, are becoming common. The 3rd generation exhibits less decompositional structuring than the second one, but still to a higher degree than the 1st generation.

```
Structuring  (Decomposition)

1st Generation          2nd Generation            3rd Generation

Stem &  Leaf

0 |                     0 |                       0 |
1 | 005                 1 | 005                   1 |
2 | 000000              2 | 00                    2 | 000005
3 | 000                 3 | 00                    3 | 000
4 | 05                  4 | 000                   4 | 0000
5 | 0                   5 | 0                     5 |
6 | 0                   6 | 00                    6 | 005
7 |                     7 | 000                   7 |
8 |                     8 |                       9 |
```

Figure 26. Stem and leaf plot for *Structuring (Decomposition).*

Structuring (Composition) did not show any change across the three generations, and the distributions are the same in shape and spread, all ranging from 0 to 4, with only one outlier in the 1st generation (Figure 27).

```
Structuring  (Composition)

1st Generation          2nd Generation            3rd Generation

Stem &  Leaf

0 | 00                  0 | 00                    0 | 0
1 | 000                 1 | 000                   1 | 000555
2 | 00000               2 | 00000                 2 | 000
3 | 0000                3 | 00000                 3 | 0000
4 | 0                   4 | 0                     4 | 00
5 |                     5 |                       5 |
6 | 0                   6 |                       6 |
```

Figure 27. Stem and leaf plot for *Structuring (Composition).*

Data modeling reveals that for the 2nd generation there was only an increase in the spread of the values, with one case scoring lower than the outlier in the 1st generation. The stem and leaf plot (Figure 28) shows that there were more cases in the higher range of the scale, thus indicating a tendency to improve. Concerning the 3rd generation, although there was only one outlier, who scored 10, there was a tendency of the scores to concentrate in the 5 to 7 range, without getting lower than 3.5, with only one case with this value. Thus, although the improvements are not dramatic there is a tendency, varying with the generation, of the cases to concentrate in the range of scores from 5 to 7, and an increase in the number of cases that score from 8 up.

Data Modeling

Stem	1st Generation Leaf	Stem	2nd Generation Leaf	Stem	3rd Generation Leaf
0		0	0	0	
1	5	1		1	
2		2		2	
3	0	3	0000	3	00000
4	555	4	00	4	00
5	00005	5	00	5	000555
6	00	6	0	6	0555
7	000	7	000	7	00
8	0	8		8	
9		9	000	9	
10		10		10	0
11		11		11	

Figure 28. Stem and leaf plot for *Data Modeling*.

The dynamics of interactions is one aspect in which there is the most dramatic improvement, consistently across generations. As shown in the stem and leaf plots (Figure 29), in the first generation, eleven cases scored 1, three cases scored 2 and two cases scored 0. In the 2nd generation, nine cases scored 2, four cases scored 4 and there were two outliers, one scoring 0 and one scoring 5. This trend of improvement was continuing also in the 3rd generation, in which the scores were shifted upwards, with four cases scoring 3, four cases scoring 4 and two cases scoring 5.

```
Dynamics of interactions

1st Generation           2nd Generation             3rd Generation

Stem &  Leaf

0 | 00                   0 | 0                      0 | 0
1 | 00000000000          1 | 0                      1 | 0
2 | 000                  2 | 000000000              2 | 0000
3 |                      3 | 0000                   3 | 0000
4 |                      4 |                        4 | 0000
5 |                      5 | 0                      5 | 00
6 |                      6 |                        6 |
```

Figure 29. Stem and Leaf Plot for *Dynamics of interactions*.

The variable *Breakdown* (Figure 30), followed a different pattern. In the first generation 50% of the cases scored 2, and the remainder were equally distributed from 3 to 0.5 as the lowest. In the 2nd generation the same percentage scored 2, but more cases score 0.5 and one scored 0. This indicates that there was no substantial variation, only the fluctuation of a few cases in the lower end of the scale. On the other hand, in the 3rd generation there is a slight improvement due to more cases in the 1 and 1.5 levels for the scores.

```
Breakdown

1st Generation          2nd Generation          3rd Generation

Stem &  Leaf

0 |                     0 | 0                   0 |
0 | 55                  0 | 5555                0 | 55
1 | 000                 1 | 0                   1 | 000
1 | 555                 1 | 55                  1 | 55555
2 | 00000000            2 | 00000000            2 | 000000
```

Figure 30. Stem and leaf plot for *Breakdown*.

Textual communication (Figure 31) definitively increases in the 2nd generation, with 13 cases in the range 2-3, against the 10 cases who scored 1 in the 1st generation, and in the 3rd generation there is a greater spread of the scores, with three cases scoring 0.5 and three cases in the 1-1.5 range. This indicates a slight decrease with respect to the 2nd generation but still a notable increase with respect to the 1st generation.

```
Textual communication

1st Generation          2nd Generation          3rd Generation

Stem &  Leaf

0 |                     0 |                     0 | 555
1 | 0000000000          1 | 00                  1 | 005
2 | 00000               2 | 0000055             2 | 0055
3 | 0                   3 | 000000              3 | 0055
4 |                     4 | 0                   4 | 05
5 |                     5 |                     5 |
```

Figure 31. Stem and leaf plot for *Textual communication*.

Hypertextual communication (Figure 32) is the other dimension in which improvements were most evident. As shown in the stem and leaf plots, hypertextual communication was symmetrically distributed and ranging from 0 to 4 in the 1st generation, with 7 cases in the median value (i.e., 2). In the 2nd generation most of the scores concentrated in the range 3-4, with the lowest value being 1 and two cases scoring 6. Analogously, for the 3rd generation the increased value was sustained, with an additional slight increase in concentration of the cases towards the upper end of the scale.

```
Hypertextual communication

1st Generation         2nd Generation          3rd Generation

Stem &  Leaf

0 | 005                0 |                     0 | 0
1 | 00                 1 | 00                  1 | 0
2 | 0000005            2 | 00                  2 | 0
3 | 00                 3 | 0000                3 | 0055
4 | 00                 4 | 000                 4 | 0055
5 |                    5 | 000                 5 | 05
6 |                    6 | 0                   6 | 00
7 |                    7 | 0                   7 | 0
8 |                    8 |                     8 |
9 |                    9 |                     9 |
10|                    10|                     10|
```

Figure 32. Stem and leaf plot for *Hypertextual communication.*

The significance of the changes across the three generations was tested by performing a one-way ANOVA, after eliminating two outliers in the 1st generation, two outliers in the 2nd generation and one outlier in the 3rd generation. The results are reported in Table 15.

Table 15. ANOVA for dimensions of design quality across generations

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Domain modeling specificity	Between Groups	5.047	2	2.524	3.163	.053
	Within Groups	31.918	40	.798		
	Total	36.965	42			
Structuring (Decomposition)	Between Groups	10.944	2	5.472	2.464	.098
	Within Groups	88.846	40	2.221		
	Total	99.791	42			
Structuring (Composition)	Between Groups	.321	2	.161	.123	.885
	Within Groups	52.376	40	1.309		
	Total	52.698	42			
Data Modelling	Between Groups	2.298	2	1.149	.378	.688
	Within Groups	121.679	40	3.042		
	Total	123.977	42			
Dynamics of interactions	Between Groups	27.133	2	13.566	14.554	.000
	Within Groups	37.286	40	.932		
	Total	64.419	42			
Breakdown	Between Groups	.143	2	7.15E-02	.177	.838
	Within Groups	16.148	40	.404		
	Total	16.291	42			
Textual communication	Between Groups	8.085	2	4.043	4.642	.015
	Within Groups	34.833	40	.871		
	Total	42.919	42			
Hypertextual communication	Between Groups	30.255	2	15.128	5.364	.009
	Within Groups	112.814	40	2.820		
	Total	143.070	42			
Complexity	Between Groups	602.583	2	301.292	.296	.745
	Within Groups	39659.5	39	1016.911		
	Total	40262.1	41			

The results of the F omnibus test shown in Table 14 indicate that significant changes across the three generations occurred for the design dimensions: Dynamics of interactions, Textual Communication and Hypertextual Communication. Domain modeling specificity just misses significance ($p = .053$).

Post-hoc comparisons for *Dynamics of interactions* and *Textual communication* using the Dunnet T3 test (for such variables the Levene test for equality of variance was significant, $p<0.5$) indicate that:

1. for *Dynamics of interactions,* both the 2nd and the 3rd generations increased significantly with respect to the 1st generation (Mean difference = 1.14 and Mean difference = 1.93, respectively, $p<.05$);
2. for *Textual communication* the 2nd generation increased significantly with respect to the 1st generation (Mean difference = 1.00, $p<.05$).

Concerning *Domain modeling specificity* and *Hypertextual communication,* post-hoc comparisons using the Tukey Test indicated that:

1. for *Domain modeling specificity,* the 2nd generation differed significantly from the 1st generation (Mean difference = 0.82, $p<.05$);
2. for *Hypertextual communication,* both the 2nd and the 3rd generations increased significantly with respect to the 1st generation (Mean difference = 1.64 and Mean difference = 1.90, respectively, $p<.05$).

In summary, the projects of the 2nd generation showed more specificity in the language used to describe the domain, more effort aimed at structuring the analysis (e.g., organization of the "stories", explicit tracing of the data and processes relative to each scenario, reflected in various representations, such as global diagrams or matrices), as shown qualitatively from the stem and leaf plot of Figure 27 (see also boxplots in Appendix C), and an increased attention towards modeling the dynamics of interactions.

Tapping more communication modalities, both textual and hypertextual, was also a distinctive mark of the 2nd generation. In the 3rd generation, the significant increase in dynamics of interactions and hypertextual communication was confirmed. There was some variation in structuring and textual communication, but more positive signals of improvement in data modeling and breakdown. The index of complexity remained practically unchanged across the three generations.

Analysis of the correlations among the design dimensions of the cases of the 2nd generation, and among the dimensions of the cases of the 3rd generation, can be illuminating in characterizing the "emerging" quality of the new generation's projects and in interpreting the effects achieved with the shared memory. The correlations were obtained by taking out from each sample the cases that were identified as outliers. A brief characterization of the outlier cases is deferred until after the discussion of the correlations.

6.3 Correlations in the 2nd generation

As discussed in section 6.1, before analyzing the nonparametric correlations among the design dimensions in the 2nd generation, Bartlett's sphericity test was performed after eliminating the outlier cases and transforming the variable *Breakdown*, for a total of 13 cases. The test was significant (Chi-Square = 11.23, df=66, $p < .05$). The significant nonparametric correlations discussed in the following are consistent with the correlations obtained when the sphericity test was performed, which are reported in Table 16.

For the 2nd generation, two particular set of correlations (Table 17) are of interest: 1) *Data modeling* is correlated with *Structuring-decomposition* (Spearman $\rho = .867$, $p<.05$) and with *Team average GPA* (Spearman $\rho = .562$, $p<.05$); 2) *Dynamics of interactions* is correlated with *Communication visual-hypertextual* (Spearman $\rho = .761$, $p<.05$). *Structuring-decomposition* and *Hypertextual Communication* are correlated, also (Spearman $\rho = .538$, $p<.05$).

Considering that the activities of structuring and representing occur at the outset of the design process that eventually culminates in the definition of the two fundamental and complementary components, i.e., the data models (the more static, semantic component) and the dynamics of interactions (the component involving the understanding of how the data will be modified within the system, and how they will be interfaced with the end users), the correlations suggest that:

- Increased structuring co-occurs with increased quality in the data modeling;
- Increased hypertextual communication, which inherently carries a temporal component related to animations and a structuring component related to the layering of information, co-occurs with a better understanding and quality of the dynamical aspects of the system being designed. Evidence of the relationship between hypertextual communication and structuring is found in the significant correlation found between the two.

This latter result of the internal analysis of the characteristic of design is consistent with results of the qualitative analysis of the generations, because generational increases in hypertextual communication and structuring co-occurred with the generational increases in dynamics of interactions.

Correlation Matrix

		Domain modeling specificity	Structuring (Decomposition)	Structuring (Composition)	Data Modelling	Dynamics of interactions	Breakdown	Textual communication	Hypertextual communication	Complexity	Team average g p a	Team overall p.r. competence	Domain Knowledge
Correlation	Domain modeling specificity	1.000	-.525	.184	-.448	-.323	.329	.285	-.397	-.397	-.245	.130	-.068
	Structuring (Decomposition)	-.525	1.000	.447	.932	.278	.175	.040	.551	-.183	.543	.387	.323
	Structuring (Composition)	.184	.447	1.000	.575	.123	.082	.227	.339	-.106	.352	.340	.403
	Data Modelling	-.448	932	.575	1.000	.178	.086	.137	.483	-.122	.561	.338	.297
	Dynamics of interactions	-.323	.278	.123	.178	1.000	-.342	-.085	.813	-.346	-.143	.245	.365
	Breakdown	.329	.175	.082	.086	-.342	1.000	-.158	-.065	-.293	.282	.270	-.112
	Textual communication	.285	.040	.227	.137	-.085	-.158	1.000	-.043	-.518	-.031	.198	.482
	Hypertextual communication	-.397	.551	.339	.483	.813	-.065	-.043	1.000	-.230	-.033	.244	.449
	Complexity	-.397	-.183	-.106	-.122	-.346	-.293	-.518	-.230	1.000	.073	-.641	-.331
	Team average g p.a.	-.245	.543	.352	.561	-.143	.282	-.031	-.033	.073	1.000	-.008	.288
	Team overall p.r. competence	.130	.387	.340	.338	.245	.270	.198	.244	-.641	-.008	1.000	.364
	Domain Knowledge	-.068	.323	.403	.297	.365	-.112	.482	.449	-.331	.288	.364	1.000
Sig (1-tailed)	Domain modeling specificity		.033	.274	.062	.141	.136	.172	.090	.090	.210	.336	.412
	Structuring (Decomposition)	.033		.063	.000	.179	.284	.448	.025	.275	.028	.096	.141
	Structuring (Composition)	.274	.063		.020	.345	.395	.228	.128	.365	.119	.128	.086
	Data Modelling	.062	.000	.020		.280	.389	.327	.047	.345	.023	.129	.162
	Dynamics of interactions	.141	.179	.345	.280		.126	.391	.000	.123	.320	.210	.110
	Breakdown	.136	.284	.395	.389	.126		.303	.417	.166	.175	.186	.358
	Textual communication	.172	.448	.228	.327	.391	.303		.445	.035	.460	259	.048
	Hypertextual communication	.090	.025	.128	.047	.000	.417	.445		.225	.457	.211	.062
	Complexity	.090	.275	.365	.345	.123	.166	.035	.225		.406	.009	.134
	Team average g p.a.	.210	.028	.119	.023	.320	.175	.460	.457	.406		.489	.170
	Team overall p.r. competence	.336	.096	.128	.129	.210	.186	.259	.211	.009	.489		.111
	Domain Knowledge	.412	.141	.086	.162	.110	.358	.048	.062	.134	.170	.111	

n= 13 (listwise); Bartlett's Sphericity Test (Chi-Square 110.23, df = 66, $p<.05$)

Table 16. Correlations among design dimensions and team characteristics in the 2nd generation (Bartlett's sphericity test)

Correlations

Statistics			Domain modelling accuracy	Structuring (Decomposition)	Structuring (Composition)	Data Modelling	Dynamics of interactions	Breakdown	Textual communication	Hypertextual communication	Complexity	Team average g.p.a.	Team overall p.r. competence	Domain Knowledge
Spearman's rho		Domain modelling accuracy	1.000	-.433	.313	-.476	-.154	-.213	.263	-.341	-.174	-.207	.092	-.263
		Structuring (Decomposition)	-.433	1.000	.428	.867**	.306	-.047	.101	.538*	.073	.425	.415	.518
		Structuring (Composition)	.313	.428	1.000	.462	.074	-.011	.300	.292	.105	.355	.339	.316
		Data Modelling	-.476	.867**	.462	1.000	.076	-.060	.035	.456	-.016	.562*	.316	.468
		Dynamics of interactions	-.154	.306	.074	.076	1.000	.421	.000	.761**	-.216	-.163	.231	.431
		Breakdown	-.213	-.047	-.011	-.060	.421	1.000	.288	.102	.226	-.262	-.213	.304
		Textual communication	.263	.101	.300	.035	.000	.288	1.000	-.113	-.235	-.042	.113	.487
		Hypertextual communication	-.341	.538*	.292	.456	.761**	.102	-.113	1.000	-.157	.038	.182	.493
		Complexity	-.174	.073	.105	-.016	-.216	.226	-.235	-.157	1.000	.213	-.527	-.307
		Team average g.p.a.	-.207	.425	.355	.562*	-.163	-.262	-.042	.038	.213	1.000	-.055	.188
		Team overall p.r. competence	.092	.415	.339	.316	.231	-.213	.113	.182	-.527	-.055	1.000	.355
		Domain Knowledge	-.263	.518	.316	.468	.431	.304	.487	.493	-.307	.188	.355	1.000
	Sig. (2-tailed)	Domain modelling accuracy		.122	.275	.086	.599	.465	.364	.232	.551	.497	.764	.409
		Structuring (Decomposition)	.122	.	.127	.000	.288	.874	.731	.047	.804	.148	.159	.084
		Structuring (Composition)	.275	.127	.	.096	.801	.970	.298	.310	.721	.234	.258	.317
		Data Modelling	.086	.000	.096	.	.795	.838	.905	.101	.958	.046	.293	.125
		Dynamics of interactions	.599	.288	.801	.795	.	.134	1.000	.002	.459	.595	.448	.162
		Breakdown	.465	.874	.970	.838	.134	.	.318	.729	.437	.388	.484	.337
		Textual communication	.364	.731	.298	.905	1.000	.318	.	.702	.419	.891	.712	.108
		Hypertextual communication	.232	.047	.310	.101	.002	.729	.702	.	.593	.902	.552	.104
		Complexity	.551	.804	.721	.958	.459	.437	.419	.593	.	.485	.064	.331
		Team average g.p.a.	.497	.148	.234	.046	.595	.388	.891	.902	.485	.	.858	.559
		Team overall p.r. competence	.764	.159	.258	.293	.448	.484	.712	.552	.064	.858	.	.258
		Domain Knowledge	.409	.084	.317	.125	.162	.337	.108	.104	.331	.559	.258	.

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

n= 13 (listwise);

Table 17. Nonparametric correlations among design dimensions and team characteristics in the 2nd generation

However, the significant increase in structuring did not result in an equivalent increase for the data modeling dimension, which only improved slightly across the two generations. On the other hand, the positive correlation between *Data modeling* and *Team GPA* might explain why this aspect of the design is more resistant to self-correction due to the shared memory. This runs contrary to the benefits that ought to accrue from structuredness, following the rationale of structured design methodologies (e.g., Cutts, 1991) and the arguments of proponents of quality in data and conceptual models (Wand & Wang, 1996; Lindland et al. 1995), and as the correlation found between *Structuring* and *Data modeling* would suggest. A higher GPA, at this stage in engineering studies (second year), is strongly indicative of general analytical abilities, and this could be a factor that accounts for more variance in the quality achievable in the data modeling activities than factors such as more sophisticated ways of tackling decomposition, increased exposure to cases, or some degree of practical initiation to database design.

On the other hand, the dimensions that significantly improved in the 2nd generation, i.e., the specificity of the language for modeling the domain, the dynamics of the interactions and the quality of textual and hypertextual communication, which are equally fundamental for the overall pragmatic quality of the design, were not correlated with the design team characteristics. The various types of teams were fairly represented in the sample, as shown in the crosstabulation reported in Figure 33. The two outliers that were taken out from the sample were both in the category of low GPA and p.r. competence 2 and 3, respectively, but, as will be discussed in the section to follow, they resulted in two radically different situations. This suggests that team typology does not determine any particular advantage or disadvantage concerning the possibility to benefit from StoryNet, at least in those dimensions more susceptible to improvement. This is quite encouraging, given the widespread variety in the type of team composition (Figure 22) that is inherent in the social context in which StoryNet is functioning.

Team overall p.r. competence * Team average GPA Crosstabulation

Count

		Team average GPA				Total
		2.50	3.00	3.50	4.00	
Team overall p.r. competence	1.00	1	1	2	1	5
	2.00	1	2	2		5
	3.00		2		1	3
Total		2	5	4	2	13

Figure 33. Crosstabulation of Team overall p.r. competence and Team average GPA in the 2nd generation.

Another signal, emerging from Table 17, is the negative correlation of *Team p.r. competence* with the *Complexity* of their design cases. Although not significant at the .05 level (Spearman $\rho = .527$, $p=.064$) it still indicates a tendency of those who are more experienced to provide less detail in their design, which can be interpreted either as their having a somewhat mature sense of what is more relevant in the analysis or as the tendency to complete the specification process at a later stage, in the prototype.

6.4 The 3rd generation

In the 3rd generation the correlations among the various design dimensions, computed by taking out the one case that was an outlier for the data modeling aspect, followed a somewhat different pattern. The sphericity test, performed after transforming the variable Breakdown, was significant (Chi-Square = 109, df = 66, p<.05). The correlations obtained when performing the sphericity test are shown in Table 18, whereas the nonparametric correlations computed on the non-transformed variables and used to interpret the results are shown in Table 19. Analogously to the analysis performed for the 2nd generation, the significant nonparametric correlations addressed in the discussion are also significant in the results shown in Table 18.

The correlation between *Dynamics of interactions* and *Hypertextual communication* seems to be a stable phenomenon (Spearman $\rho = .699$, $p<.05$); it is consistent, with the effects reported for the second generation, and their replication in the transition from the 2nd to the 3rd generation i.e., contextual increase in the emphasis in hypertextual communication and in the dynamics of the interactions. However, *Domain modeling specificity* did not increase as much as in the case of the 2nd generation, although its association with efforts in *Textual communication* was more evident (Spearman $\rho = .673$, $p<.05$).

In the 3rd generation there was also a significant correlation of each of the two above dimensions with *Structuring (Composition)*, (Spearman $\rho = .626$, $p<.05$ and Spearman $\rho = .671$, $p<.05$, respectively). Instead, in the 2nd generation this kind of association was with *Structuring (Decomposition)*. However, this is not particularly revealing, given that, as already discussed, the process of structuring is inherent to trying to communicate hypertextually. *Structuring (Composition)* was the only dimension correlated with *Team GPA* (Spearman $\rho = .558$, $p<.05$); whereas the association between *Team GPA* and *Data modeling* was not apparent. Another interesting set of correlations involved *Breakdown* with *Hypertextual communication* (Spearman $\rho = .709$, $p<.05$) and *Structuring (Composition)* (Spearman $\rho = .604$, $p<.05$).

To better understand the above results the correlation between the individual features underlying *Breakdown*, *Structuring* and *Data modeling* were analyzed. Interestingly, the 3rd generation was completely missing one of the features that define *Structuring (decomposition)*, i.e., the DFD decomposed by stories or episodes; on the other hand, all the cases in the 3rd generation had full scores on the normalization correctness (a definining feature of *Data modeling*). A correlation was found between *Team GPA* and representing explicitly the entity-to-table transformation (Spearman ρ = .626, p=.017).

Before delving into an interpretation it was checked whether the 3rd generation differed systematically from the 2nd generation concerning *Team average GPA*, *Team p.r. competence* and *Domain Knowledge*, i.e., personal knowledge of the domain to model. In this respect, there were no differences with the 2nd generation. Additionally, it must be noted that, in the context in which this study took place, there are no particular differences that can be attributed to the students' self-selected time for the exam, especially in the time span from June to November. Usually, after November the students that present themselves for the exam tend to be those who are falling behind in their academic schedule, but this situation is not part of the time frame of this study.

However, there is one key difference: the 3rd generation has additional information (or at least this information is available) concerning what were the reactions and feedback to the projects of the 2nd generation. This must be taken into account in the light of developing a comprehensive account of the processes that guide and orient learning with the support of the shared memory.

Correlation Matrix

		Domain modeling specificity	Structuring (Decomposition)	Structuring (Composition)	Data Modelling	Dynamics of interactions	Breakdown	Textual communication	Hypertextual communication	Complexity	Team average g.p.a	Team overall p.r. competence	Domain Knowledge
Correlation	Domain modeling specificity	1.000	-.023	.343	.361	.168	-.079	.670	.269	.363	.223	.079	-.371
	Structuring (Decomposition)	-.023	1.000	.361	-.123	.260	-.066	.301	-.003	-.382	.474	.262	.012
	Structuring (Composition)	.343	.361	1.000	.542	.646	-.579	.607	.635	.056	.560	-.036	-.126
	Data Modelling	.361	-.123	.542	1.000	.432	-.167	.070	.304	.367	.341	.250	-.436
	Dynamics of interactions	.168	.260	.646	.432	1.000	-.670	.292	.711	.374	.583	-.221	-.171
	Breakdown	-.079	-.066	-.579	-.167	-.670	1.000	-.304	-.833	.022	-.496	.383	-.099
	Textual communication	.670	.301	.607	.070	.292	-.304	1.000	.497	.250	.280	-.332	-.132
	Hypertextual communication	.269	-.003	.635	.304	.711	-.833	.497	1.000	.406	.230	-.391	-.173
	Complexity	.363	-.382	.056	.367	.374	.022	.250	.406	1.000	-.189	-.237	-.558
	Team average g.p.a	.223	.474	.560	.341	.583	-.496	.280	.230	-.189	1.000	.144	.202
	Team overall p.r. competence	.079	.262	-.036	.250	-.221	.383	-.332	-.391	-.237	.144	1.000	-.198
	Domain Knowledge	-.371	.012	-.126	-.436	-.171	-.099	-.132	-.173	-.558	.202	-.198	1.000
Sig. (1-tailed)	Domain modeling specificity		.470	.126	.113	.292	.399	.006	.187	.112	.232	.399	.106
	Structuring (Decomposition)	.470		.113	.344	.196	.416	.159	.496	.099	.051	.194	.485
	Structuring (Composition)	.126	.113		.028	.009	.019	.014	.010	.427	.023	.454	.341
	Data Modelling	.113	.344	.028		.070	.293	.410	.156	.109	.127	.205	.068
	Dynamics of interactions	.292	.196	.009	.070		.006	.167	.003	.104	.018	.234	.288
	Breakdown	.399	.416	.019	.293	.006		.156	.000	.471	.042	.098	.373
	Textual communication	.006	.159	.014	.410	.167	.156		.042	.205	.177	.134	.334
	Hypertextual communication	.187	.496	.010	.156	.003	.000	.042		.084	.225	.093	.286
	Complexity	.112	.099	.427	.109	.104	.471	.205	.084		.269	.217	.024
	Team average g.p.a.	.232	.051	.023	.127	.018	.042	.177	.225	.269		.320	.254
	Team overall p.r. competence	.399	.194	.454	.205	.234	.098	.134	.093	.217	.320		.259
	Domain Knowledge	.106	.485	.341	.068	.288	.373	.334	.286	.024	.254	.259	

n= 13 (listwise); Bartlett's sphericity Test (Chi-Square 110.23,, df = 66, p<.05)

Table 18. Correlations among design dimensions and team characteristics in the 3rd generation (Bartlett's sphericity test)

Correlations

			Domain modelling accuracy	Structuring (Decomposition)	Structuring (Composition)	Data Modelling	Dynamics of interactions	Breakdown	Textual communication	Hypertextual communication	Complexity	Team average g.p.a	Team overall p.r. competence	Domain Knowledge
Spearman's rho	Correlation Coefficient	Domain modelling accuracy	1.000	.054	.317	.452	.047	.219	.673**	.182	.488	.221	.081	-.378
		Structuring (Decomposition)	.054	1.000	.503	.002	.331	.285	.419	.273	-.326	.430	.280	-.104
		Structuring (Composition)	.317	.503	1.000	.565*	.626*	.604*	.609*	.671**	.182	.558*	.116	-.224
		Data Modelling	.452	.002	.565*	1.000	.395	.256	.151	.280	.505	.405	.213	-.446
		Dynamics of interactions	.047	.331	.626*	.395	1.000	.481	.273	.699**	.326	.524	-.168	-.201
		Breakdown	.219	.285	.604*	.256	.481	1.000	.417	.709**	.164	.464	-.385	-.104
		Textual communication	.673**	.419	.609*	.151	.273	.417	1.000	.534*	.349	.264	-.139	-.173
		Hypertextual communication	.182	.273	.671**	.280	.699**	.709**	.534*	1.000	.353	.213	-.323	-.344
		Complexity	.488	-.326	.182	.505	.326	.164	.349	.353	1.000	-.148	-.217	-.657*
		Team average g.p.a.	.221	.430	.558*	.405	.524	.464	.264	.213	-.148	1.000	.184	.328
		Team overall p.r. competence	.081	.280	.116	.213	-.168	-.385	-.139	-.323	-.217	.184	1.000	-.129
		Domain Knowledge	-.378	-.104	-.224	-.446	-.201	-.104	-.173	-.344	-.657*	.328	-.129	1.000
	Sig. (2-tailed)	Domain modelling accuracy	.	.848	.250	.091	.867	.432	.006	.515	.076	.447	.784	.226
		Structuring (Decomposition)	.848	.	.056	.995	.228	.304	.120	.325	.256	.125	.332	.749
		Structuring (Composition)	.250	.056	.	.028	.012	.017	.016	.006	.532	.038	.693	.483
		Data Modelling	.091	.995	.028	.	.145	.356	.591	.311	.065	.151	.464	.146
		Dynamics of interactions	.867	.228	.012	.145	.	.069	.325	.004	.256	.055	.565	.531
		Breakdown	.432	.304	.017	.356	.069	.	.122	.003	.576	.095	.174	.748
		Textual communication	.006	.120	.016	.591	.325	.122	.	.040	.221	.361	.635	.592
		Hypertextual communication	.515	.325	.006	.311	.004	.003	.040	.	.215	.464	.261	.274
		Complexity	.076	.256	.532	.065	.256	.576	.221	.215	.	.628	.477	.028
		Team average g.p.a.	.447	.125	.038	.151	.055	.095	.361	.464	.628	.	.528	.299
		Team overall p.r. competence	.784	.332	.693	.464	.565	.174	.635	.261	.477	.528	.	.690
		Domain Knowledge	.226	.749	.483	.146	.531	.748	.592	.274	.028	.299	.690	.

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

n= 13 (listwise)

Table 19. Nonparametric correlations among design dimensions and team characteristics in the 3rd generation

The interesting phenomenon highlighted by the correlations is that all the teams took into account very seriously the normalization, and, in particular, the better students focused not only on the static, semantic quality of the ERM but also started focusing on the transition from the ERM to the definition of the relational tables. This could be understood as the results of a process in which the more perceptive students have understood the limits of the advantages afforded by structuration on the ERM quality, which is only one aspect of the data modeling quality, and have started focusing on the other aspect, that is the normalization. Now this could happen for two reasons.

The normalization was the object of much discussion and criticism during the public oral examination for various cases of the 2nd generation. The same occurred for the "what can go wrong" aspect of the analysis, and frequent were the cases in which one of the examiners challenged the team to explore the consequences of an unforeseen situation on the structure of the data or on the behavior of the system. This is one powerful channel by which such aspects might have been brought to the attention of the students.

On the other hand, another explanation compatible with the previous one is that the above polarizations, which could be due to the sample size, but still are very indicative, might stem from the fact that the projects that circulated more heavily had a common matrix, i.e., no DFD associated to each story or episode, and emphasis on the intermediate representations underlying and supporting the normalization process. Such a combination of features was basically re-purposed in the new designs. Within this line of reasoning one can also speculate that the students explicitly sought projects with such characteristics, based on the "live feedback" they witnessed at the exams or heard of from friends.

Also, some evidence towards the stylistic co-occurrence of certain kinds of elements, is provided in that, in the 3rd generation, the transformation from entities to table is associated with one specific features of *Structuring (composition)*, i.e., top-down DFDs accessible from the episodes (Spearman $\rho = .527$, $p=.064$).

It must be noted that part of the information regarding the traceability of stories in the DFD, which would be lost by missing the corresponding feature in *Structuring (Decomposition)*, is also found in another feature of *Structuring (composition)*, namely the device of using colors to identify and group the interactions pertaining to a story or to an episode. The key point is that the "organizational forgetting" (maybe temporarily) of one feature can be compensated by the presence of some others, as the 3rd generation demonstrates. This leads to the question whether there are "optimal" representations, or whether the students flexibly choose and possibly transform those that are better attuned to them, until they feel confident that they can proceed to develop the database and that they are meeting the standards to successfully pass the exam.

The following analysis focuses on the opposite of organizational forgetting, i.e., on what is "remembered" and becomes more diffused across generations.

6.5 Transferring representational modes across generations

A feature by feature analysis of the projects reveals some elements that distinguish the three generations, and indicates, at the level of features, what are practices or representational modes that are becoming diffused in the new generation (Figure 34). The features were selected based on their overall correlation with the variable "generation".

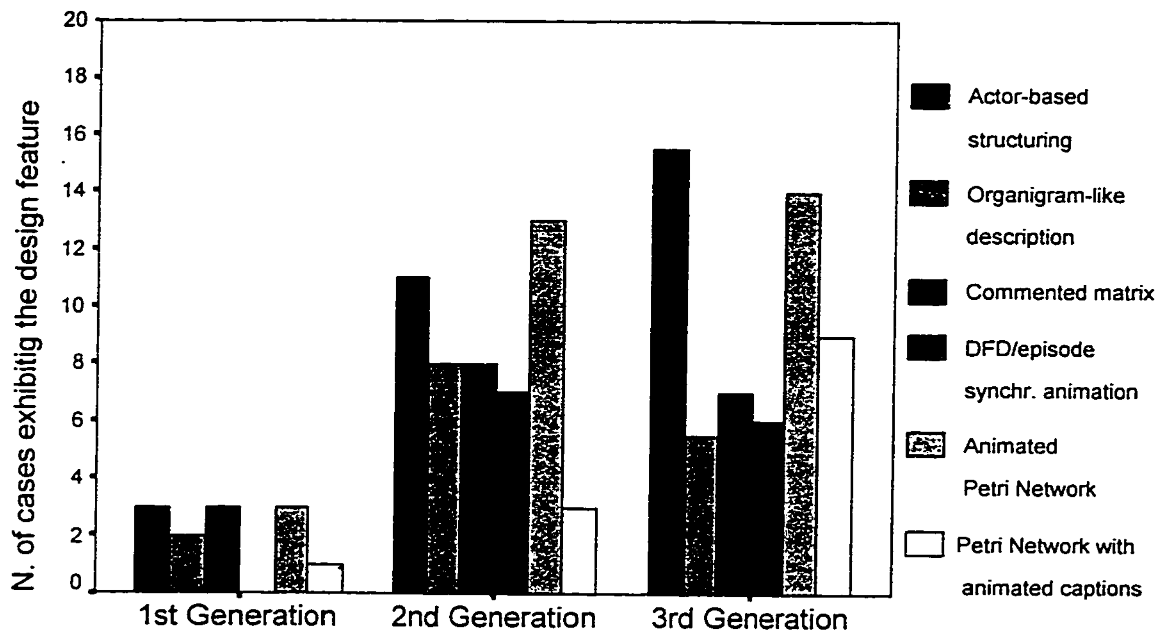


Figure 34. Design features that appear or become more diffused in the "new" generations.

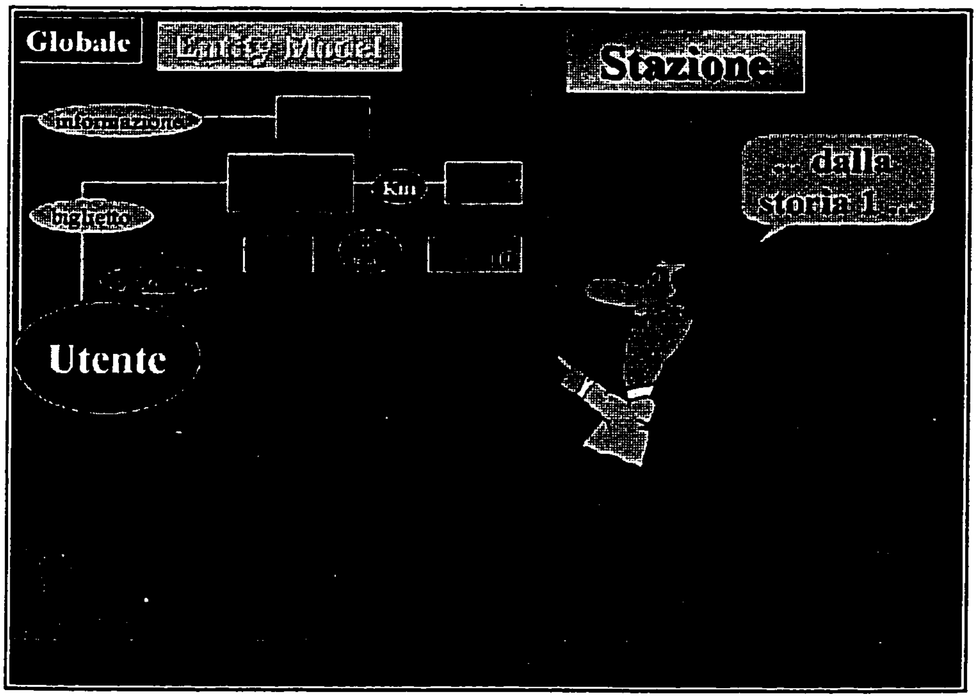
For example, the use of the animated Petri Network was quite rare in the 1st generation, but is a widespread feature in the new generation; less dramatic, although significant, is the effect for the additional self-explanation provided by animated captions. More diffused features are the use of organizational chart-like representations to give more concreteness and structure to the domain description, the use of commented cross-reference matrices and an overall approach to structuring that is more centered around "actors" rather than functions. Also, it is interesting to note the appearance of a feature that was presumably absent or very infrequent in the 1st generation, i.e., the animation of the interactions represented in the DFD in synchronization with the unfolding of the episode in which it occurs.

The interesting question arises: why are just these features passed on and diffused? Most of the above features impact on the dimensions that most dramatically improved across generations, i.e., the dynamics of interactions and the hypertextual communication. This point is addressed in the next chapter, which discusses the results in the light of the angles of analysis coming from the questionnaires and the contents of StoryNet. Some of these features are embodied by the outlier cases, others are injected because they fill a void in representational power or precisely respond to a need that was felt, by those who are more willing to experiment, or as a device to emphasize and reinforce those aspects of which one is more unsure, or those that are perceived as important in marking the distinctive identity of the project. However, one interesting side to this issue is the transformations that occur in the process, as illustrated in the following examples of re-using and reinterpreting representations.

The sequence shown in Figures 35 shows an interesting attempt in one outlier case of the 1st generation (the "Train Station") to expand incrementally the ERM in order to show how each entity derives its meaning from the stories to which it belongs. This attempt is further explored and refined in the case of the "Ski school", whose authors had the "Train Station" as a design precedent. The sequence in Figure 36 shows how this suggestion is imitated in their ERM and also carried over to the Datastore-Entity cross-reference matrix.

Figure 37 shows an explicit, graphic representation of the reasoning underlying the normalization process for one case in the 3rd generation. When present, this was described mainly textually in the former generations.

Figure 38 shows two different approaches to modeling the Petri Network, one focusing on the interactions between two actors at a time, and one presenting the global picture, still maintaining information about the contexts in which the involved actors (or processes) operate.



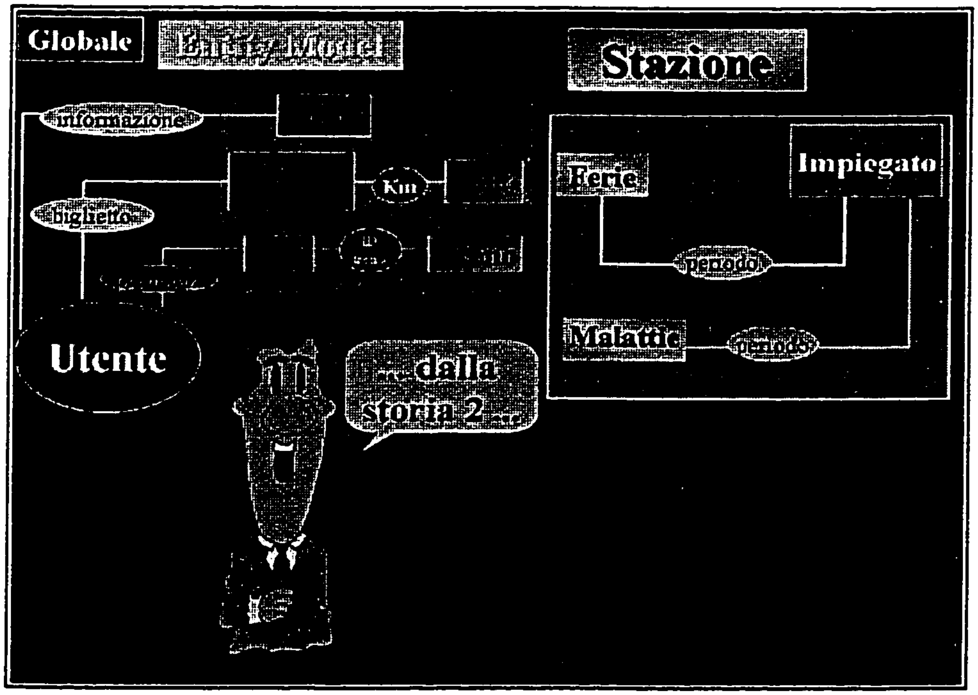
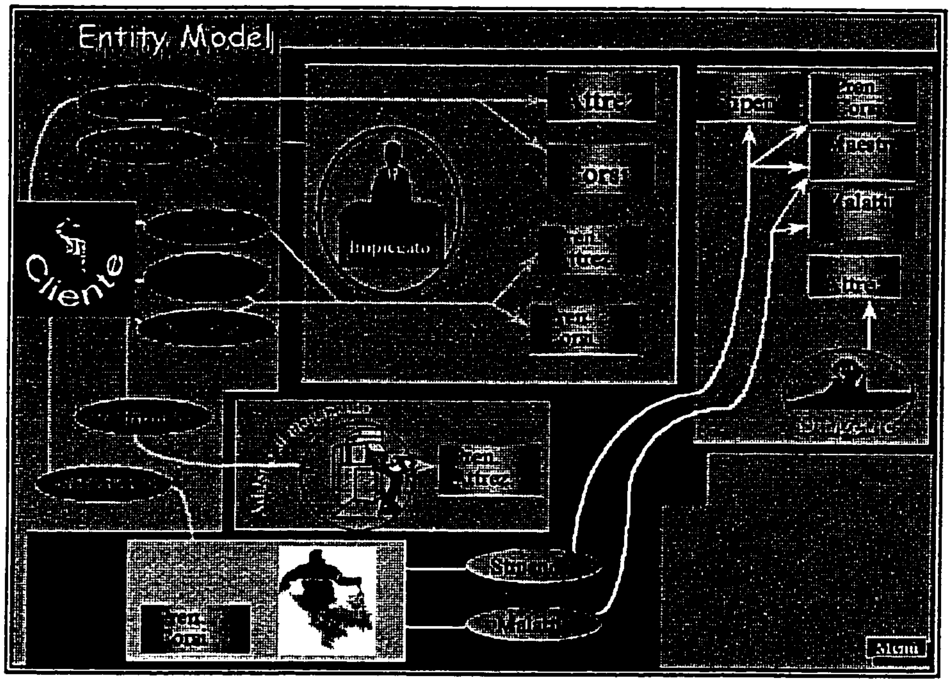
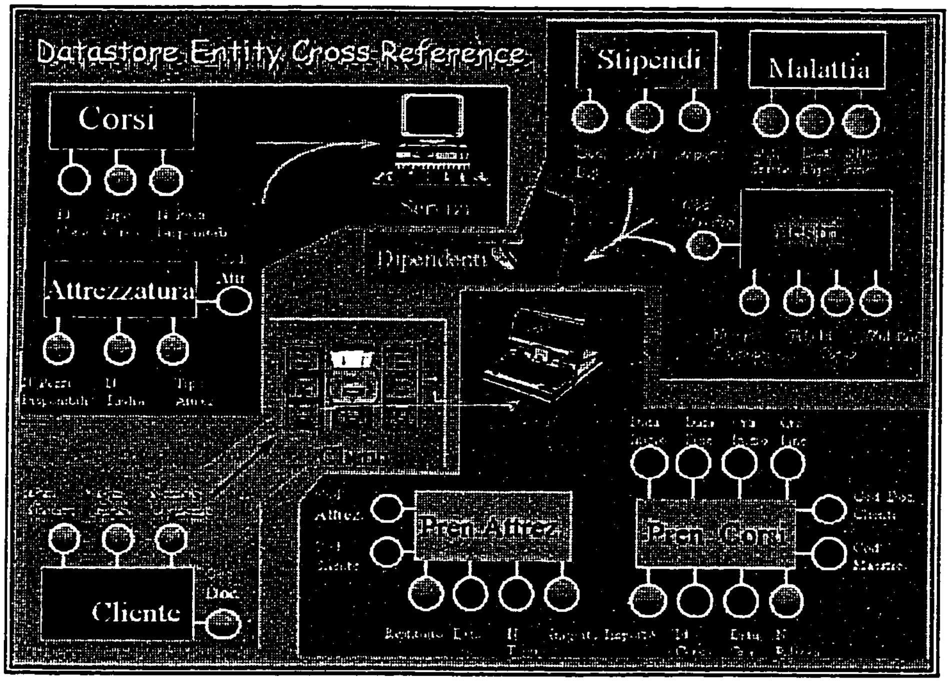


Figure 35. Tracing entities to stories in the ERM (from the "Train Station" case).





<u>Figure 36.</u> The suggestion from the "Train Station" reinterpreted in the case of the "Ski School".

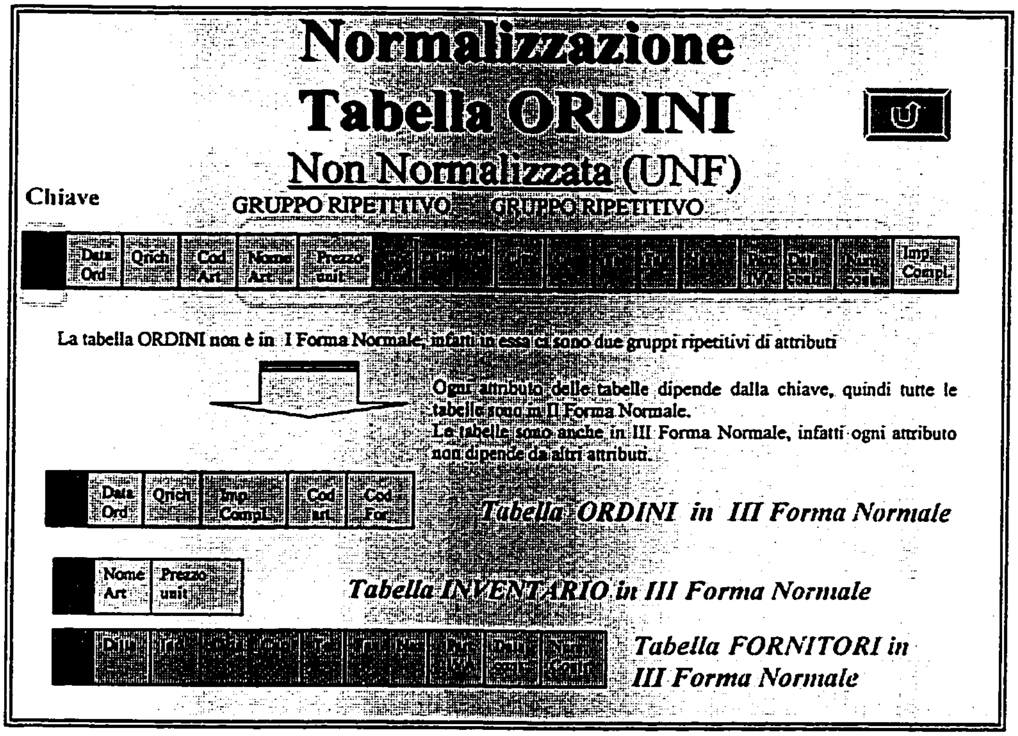


Figure 37. An explicit representation of the reasoning underlying the normalization process in one case of the 3rd generation.

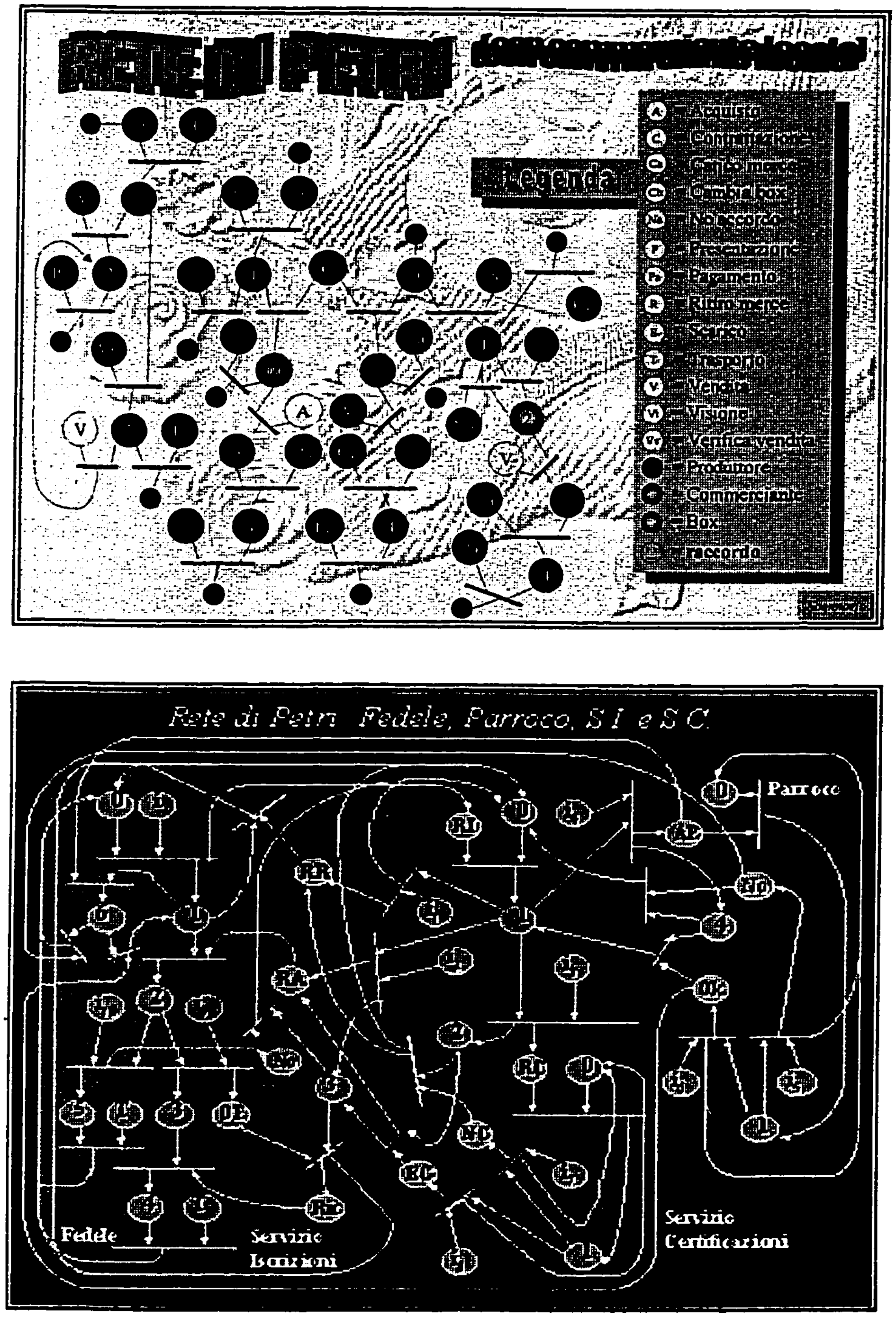


Figure 38. Two examples of Petri Networks in the 3rd generation.

Note. The first case has isolated the processes that interact with one specific actor, whereas the second case has preferred to keep the global picture, maintaining with the shadowed areas information on the contexts where the transitions take place.

6.6 Outliers across generations: three small case studies

Outliers in the 1st generation were case n.10, for *Structuring (Decomposition)*, and case n.26, an outlier in *Structuring (Composition)* with a score of 6. An analysis of the extreme values showed that the two cases ranked within the first three positions in both the structuring dimensions. Case 10 also rated among the first four in the *Data modeling* dimension. Thus these were fairly balanced projects with the specific highlight of emphasis on structuring. Case 19, an outlier for being the weaker in *Data modeling*, did not have any other particular weakness other than that. None of the above ranked in the first positions concerning the other dimensions, meaning that the sample of the 1st generation was fairly representative of different combinations of features. Cases notable for *Domain modeling specificity* and *Dynamics of interactions* are not considered outliers because of the peculiar three values distribution of these variables.

The two outliers in the second generation, both for *Dynamics of interactions* (cases n.9 and n.18) are important because they exemplify two rare situations, which have in common having apprehended precedents in the same area of the new design, but resulted in quite different outcomes.

"Anne" (not her real name) worked alone. She did not have specific experience in database design but perceived her competencies prior to enrolling at the university as being intermediate in the use of computers and novice in programming. Her GPA was in the low range. She asked at the time of agreeing on a topic for her design if she could design a system for a video-rental service, because she would probably have the opportunity of developing it for a real client. She apprehended precedents related to the topic (which were available) and also one precedent that was an outlier in the first generation (the Train Station case, from now on). She obtained this one directly from the author, who was a friend of hers. In her questionnaire she reported a very high interest in the subject and perceived its professional utility as very high. She critiqued the precedent that dealt with the video-rental service, and in her review she frequently stated that the it did not meet sufficient standards of clarity of communication, starting from using fonts too small to be readable to assuming that the audience would already know the subject. She praised the ERM but criticized the vagueness of the DFD, and remarked that the Petri Network, although clear, suffered from the lack of animation.

"Anne" was an outlier in the *Dynamics of interactions* and ranked third in *Hypertextual communication*. Her design was very consistent and very original with respect to the ones normally seen. One had the impression of being at the movies. She introduced some little original features to mark the passing of time and to keep the attention of the audience. Also the interface of her prototype was very clear. After the exam she explained that she had a passion for cartoons. Her concluding remark in the questionnaire as to what was most rewarding in her design experience was " To be able to accomplish something very serious with my fantasy".

Anne was an example of a productive and transformative use of precedents in the same field chosen for the design. She benefited from the fact that there was no serious weakness in the precedents in the data modeling, and probably from the good suggestions concerning structuring from the "Train station" which she proceeded to transform in order to give it a more user-like flavor. Her design was appreciated by the audience at the exam. Months later a few students came to the instructors' office asking specifically to see it. (Remember that StoryNet does not handle animations that show in Power Point).

The opposite situation occurred with the other case, who was a team that besides being an outlier for weak dynamics of interactions also scored the lowest for data modeling, in spite of being in the intermediate to advanced range for p.r. competence, and having specific experience with database design. They both had a low GPA. Red-Ross (not their real pseudonym) reviewed a precedent in the same field, i.e., the sporting facilities of a university campus, and pointed out that they were disoriented by a certain confusion in its organization and overwhelmed by its level of detail. In spite of their experience, Red-Ross were among the ones who utilized more precedents (five, mostly through friends). The elements that they re-used in their project were not taken from the precedent they reviewed, but from another one, in a similar field, as they explained in their links in StoryNet. In their questionnaires, they both strongly agreed that to place one's own design in relationship to others fosters innovation and precision. The one who was more experienced was categorical in asserting that it was not useful to read colleagues comments in StoryNet, whereas the one who was less experienced rated high both peers and instructor comments and critiques. In spite of the above premises, Red-Ross's integration of different representations was not particularly consistent or aimed at clarity (they also ranked third lowest in hypertextual communication).They re-purposed integrally, with the proper adaptations for their domain, an approach to representing the global ERM and other representation relevant to data modeling with the same flaws that were evident in the ones that they re-used. Nor did they clarify the nature of their data in an explicit entity to relational tables transformation, or balance their design with more attention to the dynamics of interactions. However, they introduced a variant in which they demonstrated that they were competent in practice, by tackling the issue of how the user could benefit from the system from the Internet. That is, they introduced an innovation in the conception of the problem. Their effort towards improvement was basically focused on the development of the prototpye.

This case is particularly illustrative of two issues: one is the undetected propagation in the shared memory of potentially misleading elements; the other is the interplay between use of representations and former experience. If Red-Ross had previous experience developed by practice and not supported by a formalized model or methodology, they probably developed their idiosyncratic approach to representing things, as well as a mental model of what it takes to design and develop a database, and were not particularly willing to question it. The above discussion suggests another twist to the biases of "quasi-novices", i.e., students who have already tackled some design problems but not examples that were complex to the extent that they can appreciate the advantages of learning a new way of doing things. One bias is the tendency to specify less and focus on few aspects, as already discussed. In some other cases, such as this one, the bias is to use the design representation in a way that is only personally instrumental, leaving implicit many of the key passages and without cleaning it up to the point to be self-evident to the audience. This weakness in the data modeling is not necessarily reflected in the prototype although it is a failure with respect to the pragmatic quality of the conceptual model and external user validation. This can be acceptable in the context of "craftmanship" based development activities, but it can become an hindrance when the number of the actors in the team increases or when the complexity of the system increases.

John (not his real name) was the outlier for the 3rd generation in the data modeling dimension. He became well known for the countless times he came to consult on the project, from the very beginning. He first started working in a team, in a domain with which he was familiar, but then the team broke up, after most of the conceptual model had been developed. His friend presented the exam in June, but John kept working on the project until October, refining the model and developing the prototype alone. He was not satisfied until he had made sense of all the suggested ways of looking at a design case implied in the critique guidelines and until he reached the standard that he had set for what would be a fine design, from the tackling the analysis from all the possible angles to the graphic design. He contributed one of the most insightful and thorough reviews in StoryNet, and his design also scored in the top four ranks in many other dimensions. This case, although extreme, illustrates one subtle risk of the shared design memory for those who tend to take much into account what is out there, in a conscious effort to take the best of everything, and who still are unsure as to what is "best". This can be overwhelming, especially if the task is undertaken alone, and not necessarily productive. On the other hand, the effort put out by John certainly resulted in enriching the shared memory by providing an artifact which can be considered an exemplar of a thorough, fundamentally correct design.

These three case studies highlight some points that must be taken into account in the general discussion of the results to follow in Chapter 7. First, in general, the cases first two cases suggest that it is an asset to find design precedents in the same domain of the new design, although the benefits concretize differently for complete novices and for those who already have some experience. Truly novices can be placed in a condition to finalize their efforts towards accomplishment that could otherwise be out of reach, to the point of outperforming in the outcome of teams that start from a more advantageous situation, for example by having a higher GPA or some design experience. In this respect negative examples (i.e., what is criticized in the review) have a role to play, especially if, for some fortuitous circumstances, the learner can resort to personal resources to find ways of how counteracting the perceived weaknesses. On the other hand, the possibility that a positive outlier has to become one of the new reference models is strongly related to the fact that the case is recognized as such. Whereas for Anne this happened quite naturally, for the circumstances of her oral exam, for John it did not, since he was the last of a long day of exams and when he discussed his project most of the audience was gone.

Thus it would be desirable to have in StoryNet some way to easily identify such outlier cases. To this extent it must be noted that a natural, slowly emerging indicator that can help distinguishing particularly good cases in StoryNet is the number of reviews that such cases get.

Chapter 7

Discussion

The analysis in Chapter 6 has highlighted a phenomenon of organizational learning in which the community of designers has changed in identifiable respects the quality of the design produced, and in some ways beyond the anticipated effects. In fact, the original intent behind StoryNet, was to capitalize on the richer pool of cases provided by the shared memory to provide contextualized examples of design weaknesses and strengths, for the students to learn to recognize them, emulate and advance through re-use and adaptation, hoping to offset, at the individual level, some of the more common biases and difficulties that novices face. The reasons for expecting this were the synergy with the underlying methodology for analysis and design, and added value generated by the discussion within the team members. StoryNet facilitated the placing of the links to acknowledge influences, and the sharing of insights and comments through the critiques.

Certainly, some of the individual weaknesses were offset, in the sense that in the new generations they became less frequent. For example, the specificity in the language improved; the difficulties in scoping the problem and performing decomposition were not perceived as such, as shown from the questionnaires. Nor did they emerge as weaknesses in the new designs; on the contrary, there was an increase in the structuredness of the projects, correlated with the quality of data modeling. Further, lack of referent knowledge did not appear to be a problem. It was not, predictably, for those who chose applications in a domain in which they were already knowledgeable. Those who were already familiar with the domain tended to do less complex design. If lack of referent knowledge was a problem in the former generations, manifested in the lack of specificity of the universe of discourse or in the insightfulness of the "what can go wrong" situations, it was certainly more under control in the two new generations.

However, what is striking in the results is that there is an emergent quality of the new designs beyond the point-by-point improvements, regardless of the specific characteristics of the teams. The novel semantic and pragmatic quality of their artifacts stems from a previously unachieved balance between the data modeling component and a component addressing the dynamics of interactions. These have been modeled at the process and events level, following very closely a story-based structuring and have a recognizable relevance to issues that affect the internal implementation and the interface of the prototype. Interestingly, this type of outcome is one for which there are no formal or explicit rules; it is normally conveyed by examples during classes, without receiving more emphasis than the other aspects of the design. This novel re-orientation co-occurs with an increased effort at structuring the design and at resorting to the expressive power of visual and hypertextual communication, which are both distinctive marks of the 2nd and 3rd generation. The question is therefore why the community oriented itself towards placing effort in this direction.

Starting from the various pieces of evidence collected in the analysis, a plausible account must bring into the picture the interplay of individual perceptions of relevance and utility, expectations individually and socially set, and a rethinking of the use of design representations and of the use of precedents.

One initial argument is that the activation of a "formal" shared memory, in the form of StoryNet and all the related activities to get it started, deeply affected the perceptions of the nature of the design process, re-casting it as a fundamentally communicative act. In fact, one must not forget that the informal practice of exchanging precedents was already established. But until it was made "formal" and "official", framed in the practice of reviewing and acknowledging the influence of precedents and their re-use, the overall quality achieved in the former generations did not transfer easily. One immediate consequence of the transformation, or extension, of this informal practice by acknowledging it as integral to the process of learning and designing, and asking learners to socially share a part of it, is that communication and understandability become an essential condition for recognition in the community and in the new design space being created.

The students perceived communication and understandability as one of the hallmarks of good design. But they did not understand this in abstract terms, as a design principle. They understood it through experiencing personally the results of failures in communication while examining the precedents, and by recognizing those features that were conducive to good communication. Certainly, weaknesses in communication are easier to detect than those in more sophisticated aspects of design, as it is implicitly suggested in the profile of the weaknesses highlighted in the review (Figure 24). But the implicit message in the culture of shared memory was that it was not possible to get away with sloppy communication or suspiciously obscure representations. Aiming at clarity of communication thus was one main springboard to foster deeper understanding of the domain and appropriation of the design representations.

The emergent quality of the new designs seems to be sustained by the emphasis that the learners have placed on structuring and communicating according to visual, temporal, and hypertextual modalities, and on explaining and justifying key analysis and design steps. The relationship between structuring and the above communication modalities, briefly discussed in the results section, points to the dual role of precedents in providing examples and the basic elements for the development of a more varied and refined *language of design*, so that each team could find meaningful anchors and the expressive means to engage in cycles of understandings and work towards quality in their project.

From this point of view, one argument is that the results accomplished were partially due to the special "cognitive fit"(Vessey, 1991) that was realized between the available expressive modalities and the design task in which the learners had to engage. In particular, by manipulating the basic design representation provided by the design methodology in a flexible communication medium, such as presentation software with good authoring capabilities, the resulting language has enough "built in" power that the outcome specifications are not simply descriptions of the system, but rather small simulations of it and simulations of the conceptual operations performed in key design steps (for example by illustrating how a relational table had to be split after the normalization process). The interesting side to this view is that the students can learn from the various examples how to *coordinate the design representations* in a broader discourse. Also, the simulation component greatly increases the opportunities for checking the overall correctness and consistency of the system. Thus, the indirect impact of structuring and communication on the dynamics of interaction, which is particularly welcome because the students are dealing with the analysis and design of user-centered systems with a strong interactive component, can be explained as arising from two components: 1) a varied enough pool of examples to generate the language, and 2) a perception, either from the examples or from other sources, of the value of an effective implementation of the dynamics of the interaction component.

Was the selection of certain communication modalities consciously made because there was awareness of their impact towards achieving certain design quality goals, or was it simply the result of imitation? Or were they selected because they were perceived as a goal in itself with respect to the standards to be attained for the exam, or because they afforded a safer anchor to ground and ensure personal understanding? Probably, the answer is different for each kind of team, as will be elaborated upon later. However, if one places at the core of the transformation among generations the process of selection and transformation of elementary design features or more substantial parts of precedents, performed under the premises of the shared memory, and guided by the idea of increasing the quality of the design, and if the global effect observed can be described as having increased the standards for the community, then the obvious question is to what extent the process of setting standards is self-regulated, and according to what mechanisms. Related to this question is whether the evolutionary trend can be sustained across generations or at a certain point exhibits diminishing returns.

Adaptive evolution in the shared design memory

The first trap to avoid is believing that the shared design memory is simply StoryNet. StoryNet is just one part of the distributed system that is realized, the part that is more concerned with keeping a trace of what has been done, of the artifacts that have been created, augmented by the information in the links and in the design reviews. It is the part that should develop the continuity between generations of designers and enhance the opportunities to find meaningful anchors beyond what is available through informal networks. It is the mirror against which the learners confront their new identities as designers. Around this system is the real, living and breathing community, very attentive to what happens, talking to the professor, to the assistant, coming to watch the presentations of their colleagues, engaged in a process of learning to perceive what *really* matters in design, on what standards quality will be judged.

In this respect the differences between the 3rd and the 2nd generation are illuminating. The 3rd generation quickly reoriented itself towards paying attention to those aspects that were pinpointed and discussed in the exams. Implicitly, a goal and some clues regarding the standards at which one had to aim had been reinstated. Part of the organizational learning that took place can be described as a process of successive approximation of understanding what is important, what are the marks of a good design, of a good conceptual model. The process of attributing importance is as much personal as it is social, constructed from the personal experiences, from the interpretations of the messages gathered from the classes, from the standard sources for learning the technical aspects, from the stories about colleagues who had their designs evaluated, and so on. It is a process of discovering the goals as much as discovering how to reach them. The key point is that this picture has to be constructed from pieces of information that are not meaningful, or are only partially meaningful, at the beginning.

The process that operates in the background for the diffusion of certain design features across generations can be described as one of *critical imitation*, driven by criteria of maximum instrumental utility. At the individual, concrete level, this process probably proceeds by incorporating, initiating or transforming small design features or representational devices that the students like or tentatively perceive to be supportive of the aspects they want to improve. After this initial selection process, the transformation proceeds to the point of serving one's own purposes, concerning understanding and expressiveness. From this point of view, the fact that precedents might be "suspicious" favors the transformation of the representations to the point that they become meaningful and consistent enough. The other stopping-rule for refinement, on the other hand, is provided by the perceived threshold of what is the optimum level, at that particular point in time, for presenting the exam. Definition of this level is an adaptive process, based on artifacts' availability, and mutual reference and adjustments, and live feedback. Imitation is critical because it is carried out through cycles of testing and refinement, until there is convergence on stable, shared interpretations of design features of socially acknowledged maximum usefulness or utility, that, in turn, become consolidated design practices. The fact that most of the more basic elements that are transmitted and diffused belong to the communication dimensions – visual hypertextual and structuring (Figure 34) - can be interpreted in the context of finding the suitable anchors to start building more refined understandings. Communication is certainly a starting point within the reach of the novices, and for the more advanced students it is an easy dimension to integrate.

However, a better understanding of the dynamics of artifacts space requires a closer look at the individual differences and the corresponding roles played in its evolution. The alleged "biases" of novices and semi-novices are vital. The above discussion has portrayed design construction as a process of selection and transformation of representations, guided by variety in the precedents and variety in the attribution of importance by each actor. Also presented was a view of the design of this particular kind of system (the interactive information system) that proceeds through progressive shaping, giving it structure and making it as self-explanatory as possible and as self-motivated as possible.

The designs of the novices, semi-novices and more advanced students have quite complementary strengths. The more expert were more synthetic, their designs being less detailed, as is shown by the negative correlation with complexity, but they tended to introduce "innovations", mostly in the form of taking into account aspects related to actual work practices, and to the latest technologies of which they were more aware. Although they have improved in overall communication and understandability, especially if they do not have a very high GPA, they suffer from the bias that their representations, especially in the data modeling, are more cryptic, sometimes slightly flawed, and hybrid. They take from the precedents whatever representational model they have found more convincing and develop it to the point that it makes personal sense, subsequently continuing the specification process in the software prototype. The fact that they tend to focus more on innovations marks both their willingness and desire of being recognized as more advanced students, and suggests that they have already developed a model of the external, professional world in which such an attitude is rewarded.

On the other hand, data modeling is just what the novices who have a high GPA perceive to be a terrain in which they can more successfully venture, probably because they already possess the conceptual tools to develop solutions to the point of being clean and accurate. In a certain sense, this is also a way of becoming recognized in the community. These students are a very powerful filter for the representations that do not make sense immediately or are too idiosyncratic. Although they are not particularly prone or ready to introduce innovations in the problems and in the solutions, they are quite receptive to innovative representations with increased expressive power, and sometimes they originate them.

Students that fall within intermediate situations have quite another role to play in the social system of shared memory and increase its variety. In the process of finding meaning, they extensively test the utility and viability and the representational devices of the precedents, stretching them to the extreme consequences, and sometimes introducing refreshing changes and communicative twists.

Their "bias" of thorough detailing, which is also a way of anchoring the quality of their project to the more controllable criterion of completeness, leads also to a more extensive use of all the other design representations to increase the multidimensionality of their analysis. It is almost as if the underlying process of approximating meaning and discovering notions of design relevance proceeds by incorporating all that is available, using the detailing also as a means to self-training to perceive the design forms that can accommodate the suggestions coming from the reviews of the precedents and those arising from social interactions.

This can be examplified in the approach to detailing followed by the cases of two teams, ("Gio-Cal" and "Cav-Spad") in the intermediate situation. They both chose very unique kinds of applications, in domains for which they could get first hand information, (an olive oil production firm and an agency for monitoring natural resources, respectively). The level of detail in their project aims at communicating the peculiarity of the domain and at identifying relevant ways of partitioning the system. In this respect, the students remarked that they used precedents from other domains to derive rules for detailing the system architecture. From their projects it was apparent that they adopted communicative forms suggested by the precedents but these were enhanced to deal with the level of detail that the teams thought was appropriate to deal with the complexiy of the domain (e.g., organizational charts, photographic strips illustrating the production process). They also introduced additional design representations (sometimes naive, and sometimes more intriguing) to back up the detail provided for those design steps of which they were more unsure. Interestingly, probably because of the emphasis that they placed on communication and intermediate representations, the two teams above did not fall into the trap of providing excessive analytical detail, thereby loosing sight of the underlying processes that they were modeling. Incidentally, this was the major problem of some extreme, unsuccessful cases originated by students with a very high GPA.

On the other hand, other intermediate teams who tackle more conventional applications drawing from shared memory, tend to provide a level of detail that is more focused on correcting the most evident weaknesses in the precedents, often without succeeding in addressing the more subtle issues. Also, as demonstrated in the case of "Bon-Lob", whereas the correction of design representations coming from the precedents can be quite acceptable, the effort placed towards injecting innovation in the system may result in a naive solution with very little bearing on realistic situations.

The coexistence of the tendencies described above in the shared memory may better explain how the overall standards for the community evolve. Shared memory brings the spaces generated by each group closer, and therefore makes them confrontable. To a certain extent, for each group the above biases have a mutually counteracting effect, thus everybody gains at the moment at which what is available in the artifacts space is taken into consideration, following a process of mutual adjustment to the best perceived quality standards.Uniformity or saturation is taken care of by the spontaneous innovative tendency brought in by the more advanced students, and in any case by the fact that actors traverse this space for different reasons, selecting and transforming. Indeed, a plausible interpretation is that the approach works for everybody because it increases the variety of the anchors, and because it is based on a discourse which, in terms of representations, is more articulated and flexible, a discourse which encourages learning as a research of the expressive modalities more fitting to each team. What is important is that the learners, as a community, were able to select the practices which are conducive to quality, and to find a viable way to proceed towards the goal of building a functioning prototype and a conceptual model recognizable as a valuable artifact in itself.

Chapter 8

Concluding remarks

The findings of this study contribute to an increased understanding, from a unique perspective, of the learning processes and cognition of novice analysts and designers of information systems, and thus have some implications for the design and deployment of systems analogous to the shared design memory to support the processes of individual and organizational learning. Of course, the highly situated nature of the context in which the study was conducted, in terms of cultural setting and specificity of the design task, makes it not possible to generalize all the points that have been made to other contexts. Rather, a point-by-point consideration of the various solutions that have been adopted and the consequences that have been obtained can lead to fruitful adaptations. Nonetheless, some general remarks can be made.

A shared design memory cannot exist in a vacuum, and creating it amounts either to formalizing a process that is already present, albeit in incipient form, or being prepared to invest a substantial effort to challenge the current organizational and cultural conditions, if they are not compatible with the ways in which shared memory supported by a technological artifact is expected to function. The ability of StoryNet to have an impact in a relatively short time span, was probably due to the circumstance that the process of shared memory was formalized in a way that was acceptable to its users and that did not clash with their values and with the kind of activities that would be performed normally with the resources that the shared design memory brings together. One finding that has emerged from the study is that it is unrealistic to expect that all the users will project the same kind of utility or value onto the contents of the shared memory. Thus it is important to address the issue of a case's representation in such a way that the possible diversities can be accommodated. In this respect, one strength of StoryNet was to provide enough variety both in the design representations and in the way of commenting about them (through the critiques, through the links and the comments) to allow the students themselves to tap into the ways that best match their expressive capabilities and their views of the task.

This speaks to the issue of to what extent structure can or has to be provided in such systems. In retrospect, it seems very much a matter of striking a balance between: a) finding a structure for case representation which responds to the objective nature of the task (in this specific case, the stories and episodes that formalize the scenarios of the information system) so that each individual item in the shared memory retains a pragmatic value, and b) finding ways of relating items so that the cognitive activities more relevant to the task being trained are indirectly exercised. The hypertext structure that was adopted for StoryNet was chosen to highlight trends of evolution and improvement among the design cases. In other contexts such structure could simply be thematic, or based on a classification of the type of design problems addressed. However, it must be noted that a key issue is to allow for collecting the design cases flexibly without stifling the possibility of new ways of reframing problems, and that one of the reasons why the shared memory is useful in a contributing mode is that the learners have the responsibility to contextualize their design cases. Thus the connections among cases ought to facilitate this process. Also, there is an additional kind of information in an explicit representation of the trends of evolution in the shared memory, because learning to perceive such trends is an additional anchor to the process of understanding quality and understanding the modalities of design and the process of structuring the design space.

The conditions in which the concept of shared memory seems to gain most of its instructional leverage are those in which there is a naturally occurring variation in the competencies and characteristics of the learners, and the number of learners is fairly high, so that the necessary variety in the application domain of the designs, and in the kinds of strengths and weaknesses of the proposed solutions and in the insights contributed in the comments and in the reviews, can be generated. This variety explains the peculiar role played by the shared memory as a cultural artifact and as a culture creating device: if the role of culture is to define and constrain the current context by projecting into the future expectations that are inherited from the cultural past (Cole, 1996), then a shared design memory allows newcomers to perceive this past in richer ways, and to experiment with different, possible futures, while constrained by some indications as to what it is better not to re-use, or re-purpose.

Beyond the re-use and re-purpose of concrete design examples, what was learned and generalized, or, alternatively, "transmitted" across generations, was very akin to a language, emerging from combinations of ways of doing things and representational modes. This effect suggests the possibility that shared memory might be a useful support also in contexts in which the skills to be learnt are not necessarily design, but involve the explicit use, transformation and coordination of various representations. In this regard, recent efforts in the cognitive sciences are pointing out that the use of "external representations" plays a fundamental role in problem-solving and other cognitive activities by constraining and changing the nature of the task, determining what information can be perceived and what processes can be activated (Zhang, 1997). Thus, from this perspective it seems plausible that, beyond the traditional account of design as a distinctive problem-solving activity (Goel & Pirolli, 1992), much of the processes supported by shared memory, concerned with socially acquiring a language of external representations, may be at the core of other learning situations and types of problem-solving activities, especially when what is required is *production* of external representations, rather than simply recognition of existing ones.

However, adaptation to different contexts must take into account that the effects discussed in this study were achieved under the conditions of consistency and synergy with the design methodology, and with a design medium that naturally supported the processes of structuring and simulation. Indeed, if something can be generalized it is perhaps the methodology that went beyond the initial design, to tune and further develop StoryNet and the effort of grounding it on an analysis of the tasks that are cognitively demanding for novices and on an analysis of the established practices in the context of implementation.

More related to the issues of usability of the shared memory are the challenges of managing StoryNet as an evolving system. In particular, there is the problem of dealing with cases and comments that do not add very much to the system, to avoid both indefinite growth and burdening the user with searching in too wide a space. This calls for some form of pruning that still respects the nature and ecology of StoryNet as a social system. In this regard, different policies for managing the evolution of the system using "intelligent" agents that employ neural and genetic techniques are currently under study. Although, from a representational point of view, it is plausible to estimate that the more recent projects tend to be more complete and to embody different synthesis of the best past experimentation, still there are the problems of a) identifying and leaving in the memory old designs that tackle an uncommon application, and those that are more cogently representative of strengths and weaknesses, and b) covering a time-span wide enough that patterns of transformations and evolution can be detected.

As a final remark, the need to adopt a longitudinal approach to the study of the distributed system comprising the shared memory, in order to understand the effects on both individual and organizational learning, cannot be overstated. Just as meaning can emerge for the learners through the juxtaposition of individual design cases, the comparison of different generations of designs, complemented by the information provided by students and by contents of the shared memory, has provided an insight into the dynamics of underlying processes that would have not been possible otherwise.

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Appendix A

Design Review Guidelines available in StoryNet

Scheda critica progettuale

Author: Ascentia

Date: Monday, 3/09/98 1:18 AM CET

Title:

Project:

Analisi e Modellazione Concettuale

1) **Modellazione dell'organizzazione/sistema (Business Analysis)**

- Il numero di storie/scenari analizzati e' sufficiente per caratterizzare bene l' organizzazione ?
- La articolazione/suddivisione del sistema in storie e' appropriata ?
- Si capisce la motivazione per cui viene informatizzata un parte del sistema ?
- Il problema da trattare e' espresso chiaramente ?
- Lo scopo del problema e' troppo ambizioso o troppo ristretto ?
- I casi d'uso identificati dalle storie e dagli episodi sono pertinenti ?
- Il modello e' completo ? (cioe', sono stati omessi aspetti importanti ?)
- Il modello e' accurato ? (cioe', gli aspetti descritti sono descritti in modo preciso ?)

○ mediocre ○ sufficiente ○ discreto ○ buono ○ ottimo

Perche':

Dubbi?

2a) **Modellazione delle storie**

- Le categorie del template sono applicate correttamente ?
- Il linguaggio e' sufficientemente specifico ? (cioe' i dati che vengono scambiati non sono troppo astratti o troppo generici)
- Il linguaggio e' non ambiguo ? (cioe' lo stesso termine e' utilizzato per descrivere cose diverse)

○ mediocre ○ sufficiente ○ discreto ○ buono ○ ottimo

Perche':

Dubbi?

2b) **Modellazione delle storie**

- Gli episodi nei quali sono strutturate le storie si concludono ciascuno con il raggiungimento di un obiettivo del protagonista principale ?
- Gli episodi danno luogo a scene nelle quali gli altri attori partecipanti raggiungono solo obiettivi strumentali ? (cioe' funzionali all'obietivo del protagonista della scena)
- Le relazioni che competono ad un ruolo si esplicano in uno o piu' episodi ?
- Come si ripercuote questa scelta progettuale sull'interfaccia. sia nel caso che le suddette operazioni siano raccolte in un unico episodio o strutturate in piu' episodi ?

○ mediocre ○ sufficiente ○ discreto ○ buono ○ ottimo

Perche':

Dubbi?

2c) **Modellazione delle storie**

- Sono indicate le procedure di recovery dai WCGW ?

○ mediocre ○ sufficiente ○ discreto ○ buono ○ ottimo

Perche':

Dubbi?

Qualita' dei DFD

- I dati scambiati sono ben identificati ?
- Sono completi ?
- Sono accurati ?
- I DFD sono facili da comprendere ?
- La distinzione fra archivi, dati scambiati e processi e' chiara ?

○ mediocre ○ sufficiente ○ discreto ○ buono ○ ottimo

Perche':
Dubbi?

---

4) **Qualita'degli ERM**

- Le entita' sono descritte con gli attributi ?
- La distinzione fra entita' e processi e' chiara ?
- Sono evidenziate le relazioni 1-n, n-n ?
- Sono evidenziate strutture "isa" (classi) e "consist of" (relazioni fra parti costituenti) ?
- Le entita' sono analizzate anche per aspetti ?
- Raccoglie tutte le entita' che compaiono nelle storie/episodi ?
- L'interpretazione e' non ambigua ?
- Ci sono aspetti inconsistenti ?
- L'Entity-datastore cross-reference e' fatto tenendo conto dei vari ruoli delle entita' ?

○ mediocre ○ sufficiente ○ discreto ○ buono ○ ottimo

Perche':

Dubbi?

---

5) **La normalizzazione e' ben fatta ?**

- La trasformazione di singoli attributi in entita' e' giustificata dagli scopi del progetto ?
- La suddivisione di entita' in sottoentita' ciascuna con un gruppo di attributi e' giustificata dagli scopi del progetto ?

○ si ○ no ○ non so

Perche':
Dubbi?

---

6) **La modellazione di agenti con gli automi e le reti di Petri e' corretta ?**

- I processi selezionati per essere modellati sono quelli che rappresentano o supportano direttamente gli utenti del sistema ?
- I modelli lasciano prefigurare il protocollo di comunicazione fra gli agenti allorche' uno dei due e' automatizzato ?
- Cio' che emerge dal modello da' suggerimenti sull'interfaccia del sistema verso gli utenti o sulla creazione del suo manuale d'uso ?

○ si ○ no ○ non so

Perche':
Dubbi?

---

7) **Entity-Life History**

- L'entity life history evidenzia gli aspetti di sicurezza (protezione) dell'accesso agli archivi ?
- L'entity life history e' descritto con precisione tale che emergono i metodi operanti sulle entita'? (esempio. "iscrizione", invece che "insert" relativo all'operazione di inserimento di uno studente in un archivio)

○ si ○ no ○ non so

Perche':
Dubbi?

---

8) **Process Outline**

- Il process outline mette in evidenza i diritti che i processi hanno di operare sulle entita' ?
- Il process outline mette in evidenza la dinamica con cui questi diritti possono essere attivati ?

○ si ○ no ○ non so

Perche':
Dubbi?

---

9) **Dimensionamento HW e SW**

si no non so

Perche':
Dubbi?

10) **Tutti i documenti richiesti dalla metodologia sono presenti ?**

si no

Se no, quali mancano?

11) **La presentazione del progetto e' autoesplicativa ?**

- E' comprensibile anche senza commento orale da parte degli autori?
- Cattura l'attenzione ?
- E' chiaramente leggibile ? (scelta dei colori etc.)
- E' modulare ? (cioe', sono riconosibili chiaramente le varie parti del progetto)
- E' incrementale ? (cioe', le varie parti si compongono incrementalmente)
- La granularita' (il livello di dettaglio a cui si ferma il progetto) e' tale da consentire l'implementazione ?

mediocre sufficiente discreto buono ottimo

Perche':

Implementazione database ACCESS

1) **L'interfaccia del database e' orientata all'utente ?**

- E' organizzata in modo da rendere chiare le possibili modalita' di utilizzo ?
- E' intuitiva e facile da usare ?
- Come si potrebbe migliorare?

mediocre sufficiente discreto buono ottimo

Perche':

2) **C'e' corrispondenza con gli scenari trattati nell'analisi ? (tracciabilita' con le storie)**

si no in parte

Perche':

3) **C'e' corrispondenza con la struttura transazionale degli episodi trattati nell'analisi?**

si no in parte

Perche':

4) **C'e' corrispondenza delle tabelle con gli archivi e i processi identificati nell'analisi ?**

◯ si ◯ no ◯ in parte

Perche':

---

5) **Le modalita' di utilizzo delle tabelle sono in corrispondenza con i processi e i metodi identificati nell'analisi ?**

◯ si ◯ no ◯ in parte

Perche':

---

6) **Che uso viene fatto della grafica nel programma ?**

◯ mediocre ◯ sufficiente ◯ discreto ◯ buono ◯ ottimo

Perche':

---

7) **Quali funzionalita' sono implementate (e funzionanti) nel sistema ?**

Lista

Generali

Cosa c'e' di innovativo nel progetto :

Quali funzioni sono trattate bene nell'Access :
(es. noleggio, gestione magazzino, etc)

Soluzione tecniche interessanti

Errori

- non modellizzare tutta l'informazione che fluisce (es., tutte richieste e mai ack) :

Valutazione complessiva sintetica del progetto

◯ mediocre ◯ sufficiente ◯ discreto ◯ buono ◯ ottimo

Dall'analisi di questo progetto hai (o avete) formato regole che potete applicare ad altri casi di progettazione ?

Se si, quali ?

Cosa potrebbe essere riutilizzato di questo progetto?

Appendix B

Questionnaire used to gather individual data

Questionario

Lo scopo di questo questionario e' ottenere dati sull'apprendimento della progettazione dei sistemi informativi, per vaiutare e migliorare di le metodologie e gli strumenti di supporto elettronici. Questo dati fanno parte di una ricerca condotta dall'ing. Daniela Giordano come parte della tesi di dottorato in Educational Technology sotto la supervisione del prof. Steven G. Shaw dell'Education Department della Concordia University, e con il permesso del titolare del corso di Sistemi di Elaborazione della Facolta' di Ingegneria dell'Universita' di Catania, prof. Ing. Alberto Faro.

Il questionario richiede circa 15 minuti per essere completato, e va compilato individualmente.

Le informazioni richieste nel questionario sono di carattere generale, e comunque verranno trattate in modo riservato, cioe' l'identita' del soggetto che ha compilato il questionario e' nota esclusivamente al ricercatore, e non viene assolutamente divulgata.

Mettere in busta e consegnare dopo l'esame.

Molte grazie per la collaborazione.

Questionario

Nome____
Cognome ____
Matricola______________________
Nato/a a_______________________
Eta'__________
M ☐ F ☐

Tipo di diploma_________________________________
Conseguito a___________________________________

Voto di diploma_________________________________

Corso di laurea

ingegneria elettronica ☐
indirizzo________________

ingegneria informatica ☐
indirizzo________________

Numero di corsi sostenuti fino ad ora_____________________________

Media

☐	☐	☐	☐
18/20	21/24	25/27	28/30

Livello di esperienza con il computer (prima dell'iscrizione all'universita')

☐	☐	☐	☐	☐
nessuno	principiante	intermedio	avanzato	esperto

Conoscenza di linguaggi di programmazione (prima dell'iscrizione all'universita')

☐	☐	☐	☐	☐
nessuno	principiante	intermedio	avanzato	esperto

Se si, con quali linguaggi ?

____
____
____

Conoscenze precedenti di progettazione di database

☐	☐	☐	☐	☐
nessuno	principiante	intermedio	avanzato	esperto

Se si, con quali ambienti di sviluppo ?

____
____
____

Livello di interesse per la materia

☐	☐	☐	☐	☐
molto basso	basso	discreto	alto	molto alto

L'interesse e' aumentato con l'esperienza di apprendimento ?

☐ si ☐ no

In che misura ritieni che il corso possa contribuire alla tua formazione professionale ?

☐ poco ☐ abbastanza ☐ molto ☐ non so

La percentuale di frequenza al corso e' stata?

☐ meno di 1/3 ☐ fra 1/3 e 2/3 ☐ oltre i 2/3

Riflessione sull'esperienza di apprendimento e di progettazione

Come e' stato ripartito il tempo impiegato per lo sviluppo del progetto fra la parte di analisi e la parte di sviluppo del database, includendo la visione di casi precedenti?

Visione casi precedenti ______ %
Analisi ______ %
Sviluppo ______ %

Tot. 100 %

Quante ore stimi di avere dedicato complessivamente al progetto?

N. ore____________

D1

Come reputi il livello di difficolta' della parte di analisi del progetto ?

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D2

Come reputi il livello di difficolta' della parte di sviluppo del database ?

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

Come reputi il livello di difficolta' per ciascuna delle seguenti attivita' ?

D3

- definire lo scopo del progetto e delimitarlo

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D4

- reperimento di informazioni attendibili per modellare l'organizzazione

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D5

- effettuare la decomposizione del progetto in storie ed episodi

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D6

- trovare un vocabolario non ambiguo per esprimere le storie

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D7

- verificare che il progetto tratti tutti gli aspetti necessari (completezza)

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D8

- capire quando una modifica in una parte del sistema si ripercuote sulle altre parti del sistema e valutarne gli effetti

☐ molto basso ☐ basso ☐ discreto ☐ alto ☐ molto alto

D9

Quanto pensi che la metodologia di progetto per storie sia d'aiuto nelle attivita' sopraelencate ?

☐ molto poco ☐ poco ☐ abbastanza ☐ molto ☐ notevolmente

D10

Quale pensi che sia l'attivita' piu' importante nella fase di analisi per la riuscita del progetto e perche'?

____

____

____

P1

Quanti progetti hai visionato mediamente prima e durante lo sviluppo del progetto?____________________

P2

I progetti sono stati ottenuti tramite: (barrare una o piu' caselle)

☐ professore ☐ colleghi autori ☐ colleghi non autori del progettodel progetto

P3

Quanto ti e' stato utile visionare progetti precedenti ?

☐ molto poco ☐ poco ☐ abbastanza ☐ molto ☐ notevolmente

P4

e perche' ?

____

Quanto sei d'accordo con le seguenti affermazioni ?

P5

- dalla visione di progetti precedenti si traggono vincoli e condizioni da rispettare in fase di progettazione

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo | indifferente | fortemente d'accordo

P6

Puoi darne qualche esempio ?

P7

- dalla visione di progetti precedenti si traggono aspetti specifici da riadattare al proprio problema

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo | indifferente | fortemente d'accordo

P8

Puoi darne qualche esempio ?

P9

Quali sono a tuo avviso gli elementi di progetti precedenti piu' facilmente riutilizzabili?

C1

Quanto ti e' stato utile l'esercizio di critica di un altro progetto ?

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo | indifferente | fortemente d'accordo

C2

e perche' ?

C3

Pensi che sia utile mettere l'esercizio di critica a disposizione di altri colleghi su StoryNet?

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

Quanto sei d'accordo con le seguenti affermazioni ?

P10

- riutilizzare elementi di progetti precedenti e' un aiuto per la progettazione

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

P11

- riutilizzare elementi di progetti precedenti aiuta a comprendere meglio il proprio problema

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

P12

- esaminare progetti precedenti aiuta ad astrarre regole di progettazione

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

P13

- esaminare progetti precedenti aiuta a trovare analogie con il proprio caso di progettazione

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

P14

- mettere il proprio progetto in relazione agli altri stimola ad essere piu' innovativi

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

P15

- mettere il proprio progetto in relazione agli altri stimola ad essere piu' precisi

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

C4

- l'esercizio di critica aiuta ad autovalutare il proprio progetto

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

L1

- Mettere i link in StoryNet aiuta ad esprimere meglio il ragionamento che si e' fatto durante la progettazione

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo — indifferente — fortemente d'accordo

L2

- I link in StoryNet possono essere utili ad altri progettisti studenti

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

L3

- E' tecnicamente complicato mettere i link in StoryNet

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

L4

- E' difficile prevedere come un aspetto di un altro progetto puo' influenzare vari aspetti del proprio

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

L5

- E' difficile individuare con precisione per un particolare aspetto del proprio progetto quali sono gli aspetti di altri progetti che lo hanno influenzato

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

L6

- E' difficile esprimere i commenti in forma utile e chiara

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente
d'accordo

S1

- I progetti dovrebbero essere messi in StoryNet in forma anonima

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente
d'accordo

S2

- StoryNet risulta piu' utile se gli autori di ciascun progetto rispondono alle analisi critiche dei colleghi

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

S3

- StoryNet puo' essere utile per individuare il progetto da chiedere all'istruttore

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

S4

- StoryNet puo' essere utile anche se il progetto originale non si puo' visionare

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente d'accordo

S5

- StoryNet e' in ogni caso un aiuto alla riflessione

☐ ☐ ☐ ☐ ☐ ☐ ☐

fortemente in disaccordo indifferente fortemente
d'accordo

S6

Quali elementi ritieni sia piu' utile visionare in StoryNet ?

		no	poco	molto
s61	Storie	☐	☐	☐
s62	Episodi	☐	☐	☐
s63	DFD	☐	☐	☐
s64	ERM	☐	☐	☐
s65	Commenti dei colleghi	☐	☐	☐
s67	Commenti dell'istruttore	☐	☐	☐
s68	Links	☐	☐	☐
s69	Critiche	☐	☐	☐

S7

Quali altro tipo di informazione di piacerebbe che fosse presente in StoryNet e come dovrebbe essere organizzata?

____

____

____

S8

Quanto e' facile navigare in StoryNet ?

☐	☐	☐	☐	☐
molto poco	poco	abbastanza	molto	notevolmente

S9

Quanto e' facile contribuire in StoryNet ?

☐	☐	☐	☐	☐
molto poco	poco	abbastanza	molto	notevolmente

T1

Per svolgere il progetto hai lavorato in gruppo ?

si ☐ no ☐

T2

se si, il gruppo da quanti elementi era composto ?____________________

T3

Avevi gia' lavorato con i componenti del gruppo ?

si ☐ no ☐ con alcuni ☐

T4

Qualcuno nel gruppo aveva esperienza personale nel settore che avete scelto per il progetto?

☐	☐	☐
si, io personalmente	si, qualcun altro	nessuno

T5

Per svolgere il progetto avete preferito principalmente:

☐ suddividervi i compiti ☐ operare insieme

T6

Che criteri sono stati utilizzati per suddividervi il lavoro?

____

____

____

T7

In caso di suddivisione dei compiti, quali sono state le tue responsabilita'?

____

____

____

T8

Puoi indicare, per ciascuna delle seguenti fasi, la percentuale di tempo in cui i componenti del gruppo hanno lavorato individualmente e quella in cui hanno lavorato in congiuntamente?

	Individualmente	Congiuntamente	tot
Raccolta delle informazioni sul problema	|_____|	|_____|	100%
Definizione delle storie/episodi	|_____|	|_____|	100%
Definizione dell'ERM	|_____|	|_____|	100%
Passaggio dalle entita' alle tabelle	|_____|	|_____|	100%
Dimensionamento	|_____|	|_____|	100%
Visione e critica di altri progetti	|_____|	|_____|	100%
Preparazione dei dati da inserire in StoryNet	|_____|	|_____|	100%
Creazione dell'interfaccia del prototipo	|_____|	|_____|	100%
Sviluppo di moduli e macro del prototipo	|_____|	|_____|	100%
Test del prototipo	|_____|	|_____|	100%

T9

Come valuti complessivamente l'esperienza del lavoro di gruppo ?

☐ negativa ☐ poco soddisfacente ☐ abbastanza soddisfacente ☐ molto soddisfacente ☐ notevolmente soddisfacente

T10
Cosa hai apprezzato principalmente dell'esperienza del lavoro di gruppo ?

D11
Complessivamente, qual'e' stato per te l'aspetto piu' gratificante dell'esperienza di progettazione?

D12
Se dovessi far un altro progetto, cosa cambieresti rispetto all'approccio che hai seguito questa volta?

D13
Quale lezione hai tratto dalla tua esperienza che vorresti condividere con i tuoi colleghi?

Appendix C

Boxplots for changes in design dimensions across the three design generations

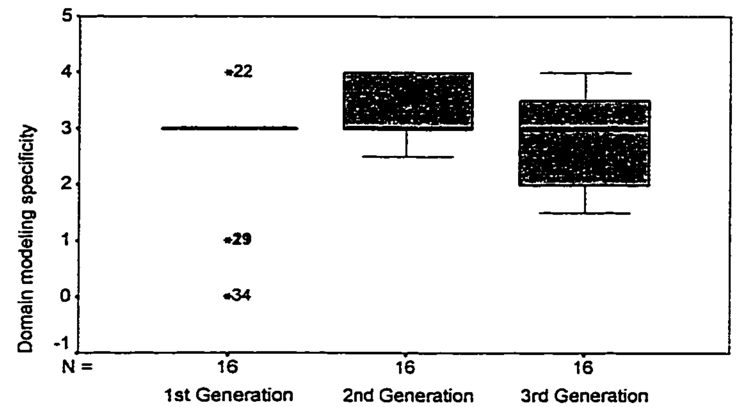

Figure C-1. Generational changes for *Domain modeling specificity.*

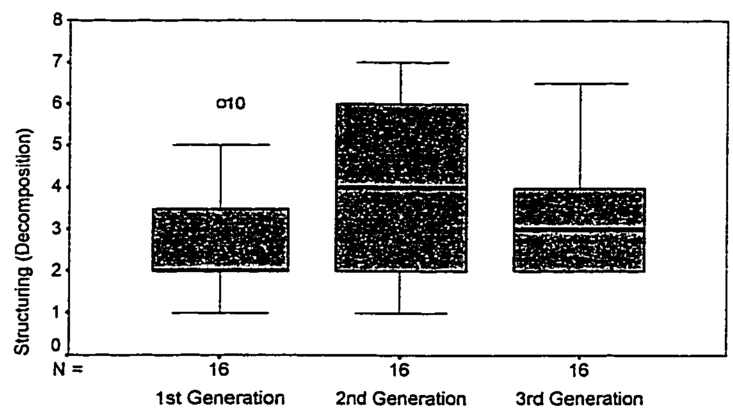

Figure C-2. Generational changes for *Structuring (Decomposition).*

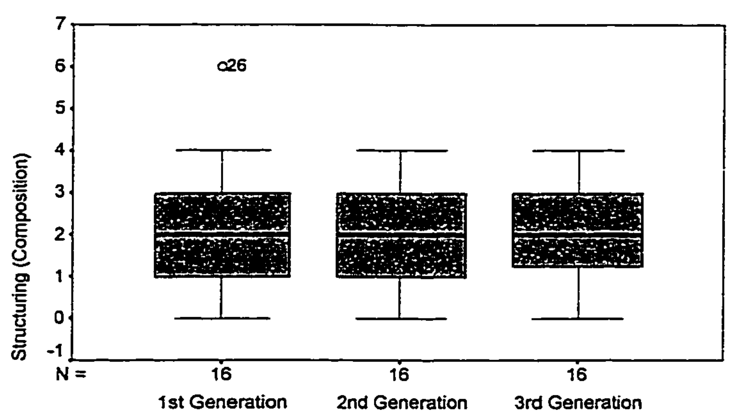

Figure C-3. Generational changes for *Structuring (Composition).*

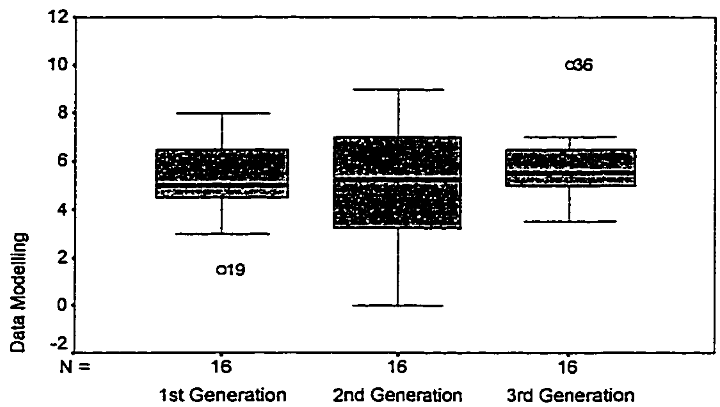

Figure C-4. Generational changes for *Data modeling.*

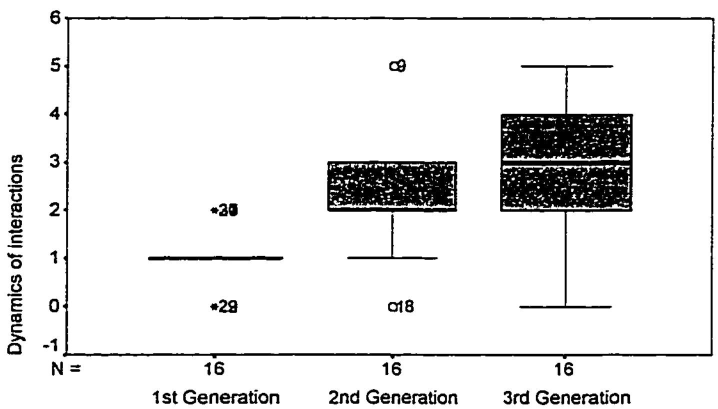

Figure C-5. Generational changes for *Dynamics of interactions.*

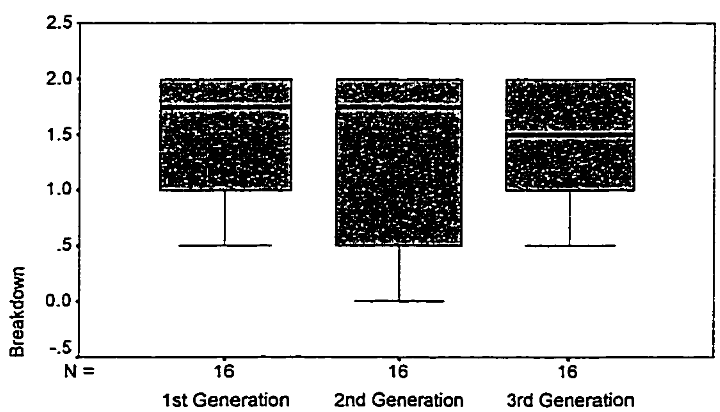

Figure C-6. Generational changes for *Breakdown.*

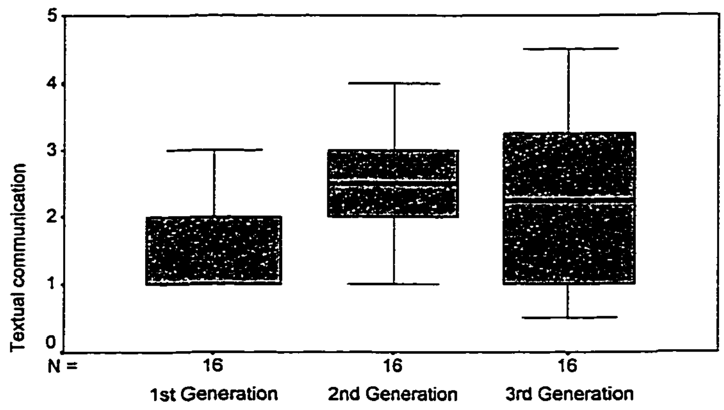

Figure C-7. Generational changes for *Textual communication.*

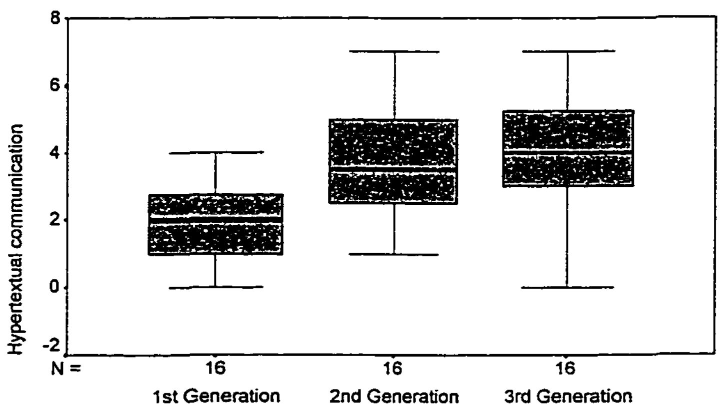

Figure C-8. Generational changes for *Hypertextual communication.*

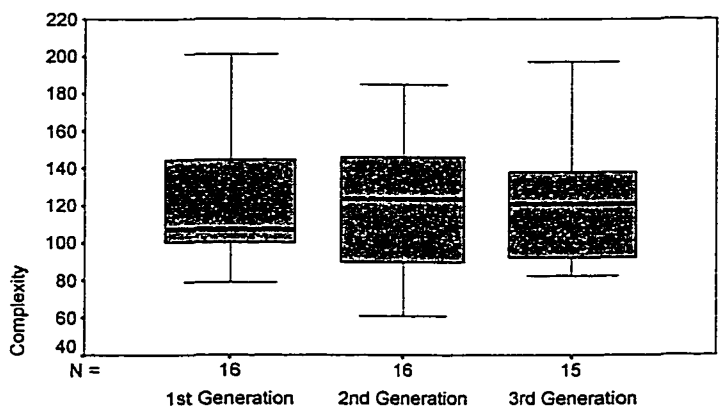

Figure C-9. Generational changes in design *Complexity.*