ICT REVISITED - FROM INFORMATION & COMMUNICATION TO INTEGRATING CURRICULA?

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SUMMARY: The paper presents a longitudinal study on the iterative implementation and testing of a support tool for precedent-based design. DYNAMO—Dynamic Architectural Memory On-line—was originally conceived as an interactive workhouse to stimulate and support student and professional architects in learning from previous design experience as encapsulated by concrete design projects. Five years after its baptism of fire, the paper looks back on how DYNAMO's role has gradually evolved from an information and communication platform to an instrument for improving curriculum integration through a process of cumulative knowledge development. After briefly recalling the underlying ideas of DYNAMO and their stepwise implementation as an operational platform, a series of case studies documents how the platform has been brought into action in different contexts—within, across and beyond architecture schools. Besides valuable feedback on DYNAMO's prototype, these case studies have generated more general insights regarding design and design tool support, which largely transcend the platform as such.

KEYWORDS: architecture, ICT, design support.

1. INTRODUCTION

Firmly rooted in the Theory of Dynamic Memory (Schank, 1982), the Case-Based Design (CBD) approach propounds that people's knowledge does not only consist of abstract, generally applicable principles, but also of specific experiences, so-called cases (Riesbeck and Schank, 1989, Kolodner, 1993). Moreover, it claims that human memory is dynamically changing with every new experience. Several years of observing and analysing people's remindings have nurtured the hypothesis that experiencing, understanding, remembering and learning cannot be separated from one another. Our understanding grows by trying to integrate new things with what we already know. As a result, understanding causes us to come across old experiences as we process new ones. A side yet significant effect of this process of understanding is that memory never behaves exactly the same way twice, since it changes as a result of its own experiences. As experiences are recalled and used, memory gets an opportunity to try out the knowledge associated with them. This allows memory to re-organize and re-define itself dynamically, in other words to learn from its experiences (Kolodner, 1993).

Learning from experience can occur in different ways (Riesbeck and Schank, 1989). New episodes are stored in terms of old expectations generated by previous experiences. Eventually expectations that used to work may have to be invalidated. Indices to unique experiences that were once useful will cease to do so because similar experiences have been encountered. In short, memory learns from experience by acquiring new cases, grouping similar cases, or re-indexing cases stored improperly at first.

Learning from experience plays a key role in architecture and, more in general, in design. Architects' education heavily relies on learning in action, i.e. on learning through the practice of designing without being aware of

what is learnt (Schön, 1983). This implicit process of knowledge acquisition is grounded in the master-apprentice dyad, in the context of the studio setting as well as in professional practice. In both settings, novice architects do not only learn from the experience of others—be it directly from teachers, colleagues, supervisors or indirectly from designers of exemplary projects—but also by accumulating personal experience through the very act of designing. In view of this, and despite the challenges CBD poses in the field of architecture (Heylighen and Neuckermans, 2003), Schank's Dynamic Memory theory has inspired the idea to develop a Dynamic Architectural Memory On-line (DY*N*AMO) in order to stimulate and support architects' life-long process of learning from previous (design) experience. DY*N*AMO takes shape as a multimedia platform filled with a permanently growing collection of cases (i.e. records of concrete design experiences), offering students and professionals a rich source of inspiration, ideas and design knowledge, as it is. Especially in the early, conceptual stage of the design process, concrete cases provide grist for some decisions to be made.

A first prototype was built in 1998 and gradually developed into what is currently on-line as DY*N*AMO v.4.0 (http://dynamo.asro.kuleuven.ac.be). On its fifth anniversary, DY*N*AMO has been and is being used by various user groups. In the context of architectural education several experiments were set up, both at our architecture school and in collaboration with other schools, and both in design studios and in theoretical courses or seminars. In addition, DY*N*AMO has been introduced to professional architects, so as to get an impression of its relevance and usefulness for design practice.

After briefly outlining DY*N*AMO's stepwise implementation as an operational platform (section 2), an overview is given of the various contexts in which it has been brought into action (section 3), followed by a synthesis of the findings and lessons learned (section 4).

2. FROM IDEA TO IMPLEMENTATION

Inspired by the cognitive model underlying CBD, DY*N*AMO is conceived as an (inter-)active workhouse rather than a passive warehouse. It actively develops and is interactively developed by architects' design knowledge, by stimulating and supporting several modes of interaction (Fig. 1):

1. interaction among cases, for cases are labelled and linked to related cases by various features architects address during design;

2. interaction between (human) designer and (computer) memory, for users cannot only consult cases in DYNAMO, they can improve its content in various ways;

3. interaction among individual designers in different contexts and at different levels of expertise, for DYNAMO is meant for collective use by students in architecture schools and professionals in design firms;

4. and thus also interaction between practice and education in architectural design.
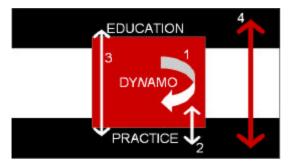

FIG. 1: DYNAMO stimulates several modes of interaction.

The development of the platform proceeded (and still proceeds) step-by-step. Each step is prepared off-line until the new version is considered ready to replace the operational on-line version. The very first prototype was built within the context of a Master's thesis (Segers, 1998, Heylighen and Neuckermans, 2000). In essence, this prototype consisted of three components:

1. a growing collection of design cases, the actual memory content. Most cases in DY*N*AMO record entire building designs, both built and unbuilt projects, and are represented by a mix of files including graphics, photos, 3D-models and text.

2. a database (Microsoft® Access 97) that organizes and structures this content. Central to DYNAMO is an indexing system that allows retrieving and browsing between design cases in multiple ways. The Access database labels every project with various features: aspects of form and space, function, construction and context. These serve as filter criteria during retrieval and as links to projects with analogous characteristics. If we consider cases as encapsulations of design knowledge, this network of links further enhances each case's value. In order to avoid confusion, a clear distinction should be made between categories and values. The term category refers to the name of an index, e.g. spatial configuration. Each category provides a place for a case to characterise itself with one or more values, e.g. cluster, linear, radial, 'plan libre'. A value thus refers to the concrete realisation of a category for a certain project. It characterises a specific project but can, and in many cases will be the same for several projects. In other words, whereas categories are chosen generally and shared by all cases, the values for these categories are assigned to each case specifically. For some categories, materials for instance, a single case can have multiple values.

3. a user interface that allows to both consult and modify memory, and can be viewed with a standard Web browser.

Using this prototype in various experiments (see section 3) has generated a considerable amount of feedback, which was taken into account as much as possible in the subsequent versions of the platform. As a result, the prototype gradually underwent the following improvements:

- The Access database was replaced by MySQL, in order to anticipate the future information growth of the case base and create a more stable platform.
- With an eye to standardisation, the existing metadata for the case files were extended into the metadata scheme of ARIADNE, conforming the IEEE LTSC Learning Object Metadata (LOM) standard (Duval, 1999). For the cases themselves, however, we opted to stick to our in-house developed, dynamic, architecture-specific indexing scheme.
- The user interface was rethought completely, in terms of layout as well as functionality, and reprogrammed anew. The categories were subdivided into three 'windows': ID (identification), design and theory. Each window allows to approach and select cases from a specific point of view. ID comprises basic characteristics such as the name of the architect(s), the location, and the year in which the project was designed or built. By contrast, the design window adopts a designer's perspective and approaches cases through aspects of form and space, construction, function, etc., while the theory window enables theoreticians to select projects by tendency or movement. Future addition of extra windows for other perspectives (e.g. history, conservation or reuse) is still possible.
- In addition, the user interface was equipped with a random browse facility and quick search function (Morisse, 2001). At this point, the former enables users to flip swiftly through photos or drawings, yet extension to include other document types (sketches, details, 3D models, …) lies within the bounds of possibilities. The quick search function may be useful when users are looking for a specific project, which they remember as particularly relevant for the task at hand. Or perhaps during their previous DY*N*AMO visit, they discovered an interesting case and want to visit it once more. To avoid having to repeat the entire search procedure again, they can access the case directly by simply typing (part of) the project name in the quick search field.
- While the first version was preferably viewed with Netscape® Communicator 4.05 (or higher) for Windows, subsequent versions tried to solve problems with incorrect functioning and display on other browsers or platforms so as to make DY*N*AMO more browser- and platform-independent.

Together these improvements have resulted in DY*N*AMO version 4.0 (Fig. 2), which currently represents 496 cases, 6402 files, 1847 keywords (index values) and 646 registered users. The user interface is on-line accessible via a standard Web browser (Fig. 3) and allows for users to consult the case base by simply specifying their selection criteria on a search page. Upon submission, the query is handled on the server by a PHP-script that bridges the gap between browser and database. This script searches the database for cases that match the query

and transmits the catch to the browser, which displays the result as a list of cases with links to the corresponding cases.
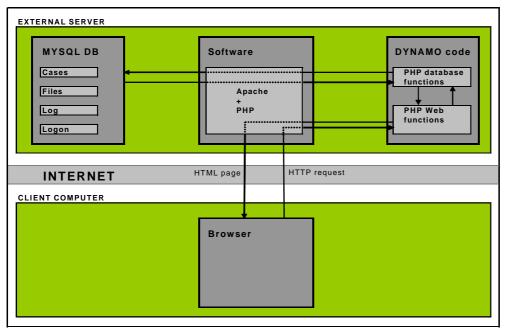

FIG. 2: Scheme of DYNAMO version 4.0

Current and future developments include:

- equipping the interface with visual keys. The visual is the way in which designers know, think and work (Cross, 1982). By consequence, if DY*N*AMO is to really support architects during design, cases should not only be represented but also accessed visually, to avoid having to leave their visual design mode. In view of this, we are developing a visual indexing and access mechanism that makes use of visual keys, small pictogram-like icons expressing an architectural feature (Neuckermans et al., 2002, Heylighen et al., 2003a). The mechanism does not only allow consulting the case base through these icons, users can also create new icons and use these to label and link cases. Rather than entirely replacing the current access mechanism, these visual keys are meant as an additional, optional interface to the case base.
- integration into the architect's design environment. A major threshold DY*N*AMO seems to be suffering from is its physical separateness from the architect's working environment. Having to leave this environment to consult a case base inconveniently interrupts the design process (see section 4). The remedy we hope to explore in the near future is inspired by the Shift+F7 shortcut in MS Word® and would connect DY*N*AMO to Idea Space, a private design space that captures and interprets architects' ideas (Heylighen and Segers, 2003). Just like this shortcut allows authors to look up synonyms in a thesaurus without having to leave the text, this connection should enable DY*N*AMO users to trigger case retrieval 'en passant', i.e. during the very act of designing.
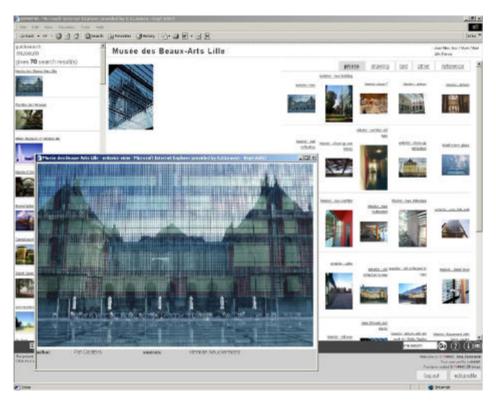
FIG. 3: Interface of DYNAMO version 4.0

3. DYNAMO IN ACTION

Having summarized the stepwise implementation of DY*N*AMO as a working prototype, this section switches attention to how this prototype has been and is being used in various contexts and by various user groups. It is so to speak a case base of DY*N*AMO experiments, and contains eight quite different case studies in different contexts and at different stages of the prototype's development. Since both success stories and less flattering experiences are stored, the level of detail and length of the case studies may vary considerably from one case to another. The case base is more or less organised in a chronological way, although some experiments partially overlap in time. Each case study starts with briefly outlining the main objective or focus of the experiment, subsequently runs through the subjects, assignment, setting and procedure. The major findings of all these experiments are grouped in the next section, which summarizes the lessons learned.

3.1 Baptism of fire

3.1.1 Focus

In Winter/Spring 1999, DY*N*AMO received its baptism of fire in an architectural design studio at its 'home base', the Department of Architecture at the University of Leuven (K.U.Leuven). Besides receiving feedback from DY*N*AMO's target public (Heylighen and Neuckermans, 2001a), the major objective of this baptism was to explore whether and how using an on-line case base in the design studio affects students' design performance (Heylighen and Verstijnen, 2003).

3.1.2 Subjects and assignment

The experiment took place in a traditional design studio addressing the issue of building reuse. The subjects were 46 fourth year architecture students, all having eight design assignments behind them. They participated in the building reuse studio as it is a mandatory subject in their curriculum. Eight of them chose to work independently, the remaining 38 grouped together into two-person teams. The studio was led by the tutor of the *Building reuse* course (also a mandatory subject), who was assisted by three studio teachers.

The students could choose as a design assignment either the conversion of a former factory hall into a public library, or the reorganization of and extension to their school, located in a 16th century castle. Both assignments

focus on dealing with an existing building, which students had to consider from multiple perspectives (e.g. formal articulation, spatial configuration, construction, materials, etc.). Four solo designers and 13 two-person teams chose the library project, the others opted for the school reorganization and extension.

3.1.3 Setting and procedure

Before the studio started, DY*N*AMO was complemented with material (primarily plans, sections and photographs) on significant reuse projects and libraries, several of which were suggested by the studio staff. At the start of the assignment, students were given a demonstration of how the platform worked. All participants were allowed to use the tool for as long and as often as they liked. By assigning each user—student or teacher— a user name and password, we could keep track of who logged on to the platform and when. The tool could be accessed not only from the computer class at school, but from every PC connected to the Internet. Students were able to consult the projects provided, write on-line comments, as well as add other cases they found relevant to the assignment. A DY*N*AMO helpdesk was set up to help students with using the tool, to answer questions and to respond to technical problems.

Aside from providing access to DY*N*AMO, the design studio was conducted as usual. Students met in the studio roughly 20 hours per week during five weeks, spending much of this time either working alone or in pairs, or discussing their project with the studio staff. After the conceptual design stage, students were given a questionnaire probing whether DY*N*AMO appealed to them and how they liked several features of the tool, such as interface, choice of cases or selection criteria.

Upon completion of the assignment, students' design projects were evaluated by both the design teachers involved in the studio and two external judges. Apart from giving an overall appreciation, they rated each project on six five-point scales each measuring a specific aspect of the design (e.g. the quality of the concept, the way the existing building was reused, or the level of creativity).

3.2 On Erasmus to Norway

3.2.1 Focus

In Winter 1999/2000, DY*N*AMO was introduced in an architectural design studio at the Norwegian University of Science and Technology (NTNU) in Trondheim. Besides exploring the platform's potential and suitability in another context, the experiment was part of a study on concept generation in architectural design (Casteleyn, 2000). In this study, a major question was to what extent (and even whether) DY*N*AMO is able to support students in architecture during the early, conceptual stage of the design process.

3.2.2 Subjects and assignment

The design studio at stake was a mandatory subject for the second year architecture students at the NTNU. It ran during six weeks, interrupted by a three-week break, and was led by four design teachers. All 61 students participating in the studio worked individually, seven of them would not complete the assignment.

Students were asked to design a ceramic museum on a site in Trondheim, squeezed between two terrace houses and connecting two parallel streets. One is a busy shopping street, the other much more quiet. Both the exterior and interior architecture had to be designed, thereby taking into account that the museum will exhibit a 5m high vase.

3.2.3 Setting and procedure

Before the start of the studio, the case base was complemented with about 20 extra museums. To this end, the studio teachers had collected a list of examples they considered relevant for the assignment. With an eye to representing various cultures and styles, the list contained museums from different countries built between 1915 and 1998.

Students were given a demonstration and handout of how DY*N*AMO works at the start of the studio, and could use the platform as often and as long as they liked. Like in the previous case study, each student was assigned a user name and password, and could access the platform from the computer class at school, or from any PC connected to the Internet.

Upon completion of their project, students were given a questionnaire asking what sources of inspiration they had used during concept generation and why, as well as specific questions regarding DY*N*AMO.

3.3 Beyond architecture

3.3.1 Focus

In Fall/Winter 2000, DY*N*AMO was called in for a study on the use of precedents in a (non-architectural) design studio. The experiment, carried out at Napier University in Edinburgh, aimed at answering questions like what thinking processes lead students to various precedents, and what precedents prove to be most useful. To this end, the study monitored not only how often students consulted the case base, but also what information was accessed and how.

3.3.2 Subjects and assignment

The subjects participating in the experiment were 39 third year undergraduate students from Napier University. Unlike in the previous two cases, they were not studying architecture, but industrial design.

The assignment involved the design of a typically Scottish restaurant within the confines of Waverly Station, the place where Edinburgh meets the world (and vice versa). The project encouraged students to examine, on the one hand, the small scale ergonomics and sensuality of eating and, on the other hand, the role of design in relation to national culture and identity. By designing the total experience right down to the fittings and furniture (e.g. chairs, tables crockery, cutlery, textiles, etc.), students were forced to rethink what it means to be Scottish, what the culture (including food and drink) is, and how people experience it. While the assignment could not be labelled as purely architectural, the role of precedent—or at least the idea that design does not take place in a cultural vacuum—was fundamental to the project.

3.3.3 Setting and procedure

Before the studio started, DY*N*AMO's case base was complemented with only two extra projects that seemed particularly relevant for the assignment.

At the start of the project, students were introduced to the platform through a demo and manual. In addition, they were taken on a tour of several "themed" restaurants, clubs, pubs around Edinburgh and Glasgow for inspiration. After these introductions, students met with their teachers in the studio two days per week for 15 weeks. Throughout this period, they could access the platform from a computer room (although not in the studio) and from home, as most of them have Internet access. With an eye to investigating the role of precedents, the assigned user names and passwords were used to monitor not only how often each student used the platform and when, but also exactly which cases they consulted, how long, how often, etc.

About halfway the studio, it turned out that students had hardly been using DY*N*AMO. According to the teachers involved, this was partly due to the nature of the project, in the sense that students would be working on the concrete physical translation of their conceptual schemes later on. However, the teachers would try and encourage them all to use the platform more over the next couple of weeks. Upon completion of the assignment, however, students' use of DY*N*AMO was still negligible, and in any case largely insufficient to even start thinking of conducting an in-depth study on the use of precedents.

3.4 Beyond the studio

3.4.1 Focus

In Fall/Winter 2000, back home at the K.U.Leuven, DY*N*AMO was introduced in a course called *Architectonic Composition and Program Studies* (Heylighen et al., 2002). The tutor came up with the idea to use the platform both as a shared resource and as a repository to collect students' work. The course is the second in a series of three on building programs and typology, dealing with housing, public buildings and spaces, and complex programmes respectively. The trio aims to tighten the bonds between theoretical courses and design studio, between 'what is' and 'how to make/design' architecture, and to lighten the design studio by providing part of the information students need for their design projects (e.g. introduction to building programmes and types, interesting examples, possibly visits, …).

3.4.2 Students and assignment

All 41 subjects in the experiment were third year architecture students at the K.U.Leuven. Having had two years of architectural education, they took the course as it is an obligatory subject in the curriculum, and grouped together into two- to four-person teams.

Each team was asked to write a paper that analyses two or three projects with the same building program. The theme of the course being public buildings and spaces, students could choose between a museum, police office, school, and public space. They were asked to unravel the projects from four points of view—urbanistic, architectural, programmatic, and constructive-technical—and to explore (whether or not present or demonstrable) relationships between them. Unlike in previous academic years, however, the idea of a classic paper was abandoned and replaced by that of a digital 'paper'. By introducing DY*N*AMO both as a shared resource for the assignment and as a repository to collect the results, the information of all analyses would become available to all students in a fast and structured way.

3.4.3 Setting and procedure

Before the start of the course, DY*N*AMO was supplemented with (digitised) high quality papers from students who had taken the course in the past.

Like in previous years, all lectures were concentrated at the start of the semester so that the information provided would be usable as soon as possible, and in any case still during that semester's design studio. In these lectures, students were given various introductions, the information of which they were to assimilate into their team work. The first lecture introduced students to the purpose and procedure of the course, and to how DY*N*AMO works. All students taking the course were assigned a user name and password and allowed to use the tool when and where they liked. A DY*N*AMO help desk was set up and would receive, all in all, 33 e-mails and some five live visits. Students met in the classroom for three extra lectures, devoted to museums, police offices, and public spaces respectively. In the meantime, they worked on their 'paper', the content of which was discussed at least twice with the course tutor. Questions regarding the format were answered during a collective question time. Since several students seemed to struggle with Web authoring, each group received a template, in which they simply had to paste their text and illustrations.

Upon submission of their 'paper' to DY*N*AMO, students were given a questionnaire in order to evaluate the experiment and several aspects of the prototype. From the 41 participants, 36 filled out the questionnaire. The course concluded with an evaluation session to give students feedback on their group work, and to ask in an informal way for comments on the 'paperless' paper experiment.

3.5 Three birds with one stone

3.5.1 Focus

In Fall 2000, the K.U.Leuven launched a two-year pilot project to examine whether and how using DY*N*AMO could improve the coherence of its architectural curriculum (Heylighen et al., 2003b). The ever more fragmentary and aspect-oriented structure of the curriculum hinders students in recognizing the coherence among different curriculum components. The intrinsically complex nature of architecture tends to multiply the number of course topics, bringing about high study loads at the expense of synthesis and reflection. Moreover, information about architecture projects in the library as on the Internet is fragmented and incomplete, and often lacks critical selection. This saddles students for each paper, design preparation or case study with time-consuming documentation work without substantial cumulative effect—information on the same project has to be collected over and over again.

In view of this, the pilot project focused on enhancing the integration between three exemplary parts of the curriculum: a course, a seminar and a design studio. Without ignoring the individual character of each, a process of synergetic and cumulative knowledge development was initiated, whereby DY*N*AMO played various roles.

3.5.2 Subjects and assignments

The pilot project involved 60 architecture students from the start of their second until the end of their third year. Other subjects involved include the tutor of the course and seminar, the four studio teachers, and two part-time assistants especially appointed for the pilot project.

As mentioned above, the project zoomed in on three representative parts of the curriculum:

1. The seminar *Program studies & building typology* (second year) critically discusses exemplary housing projects through the lens of sub- and desurbanisation, and asks students to make a typological documentation and evaluation of a local or international housing project.

2. The design studio *Urban housing* (third year) situates architecture problems in an urban context by asking students to design a high density urban housing project.

3. The course on *Architectural theory* (third year) deals with the relationship between architecture and modern urbanity, and is evaluated through a traditional oral exam.

The three were selected because, despite evident links, hardly any synergy among them was achieved in previous years. Students and teachers used to consider them as separate entities.

3.5.3 Setting and procedure

While all architecture students and teachers at the K.U.Leuven can access DY*N*AMO where and when they like, the pilot project explicitly introduced the platform in the seminar, studio and course mentioned above. In trying to respect the individual character of each, DY*N*AMO ended up playing various roles.

Within the context of the *Program studies* seminar, students had to use a specific analysis format for the typological documentation and evaluation, and to submit and present their work via the platform. In the long run, this should result in a set of uniform analyses of various projects in terms of density, lay-out, organization of collective and private spaces, housing typology and urban morphology. At short notice, DY*N*AMO enabled students and teachers to share material about the urban housing projects discussed, to learn from each other's analyses and—after the seminar had ended—to return to this material when designing an urban housing project in the following academic year.

At the start of the *Urban housing* studio, the design teachers used a selection of student analyses and extra urban housing projects to make students familiar with the design assignment. Afterwards, students could consult the material in more detail whenever they felt like. Upon completion of the studio, exemplary student projects were fed into the platform by way of example for future studios (Fig. 4).

For the *Architectural theory* course, part of the reader that students used to receive in paper format, was made available through DY*N*AMO (Heynen and Loeckx, 2003). By way of exam, students were asked to exemplify a specific design approach (e.g. Critical Contextualism), compare contrasting approaches (e.g. various projects for the same site in Berlin) or clarify concepts (e.g. type, analogy) from cases in the platform. This should stimulate students to study more in-depth the projects discussed in class, and to have a closer look at the material available instead of learning the subject matter by heart.

3.6 Destination: Practice

3.6.1 Focus

Whereas in all previous cases DY*N*AMO was used and evaluated by diverse groups of student designers, this case represents its first confrontation with professional architects (Heylighen and Neuckermans, 2001b). DY*N*AMO offers a platform for exchanging and learning from design experience in the form of cases, which perfectly chimes with today's tendency towards life-long learning and continuing education (Heylighen, 2003). Just like our university advises graduates to "*take a maintenance contract with your degree*," architecture schools may as well encourage recently qualified architects to subscribe to DY*N*AMO. Its first confrontation with practitioners aimed at investigating to what extent the platform can serve as maintenance contract, and at getting feedback on its relevance for practice.
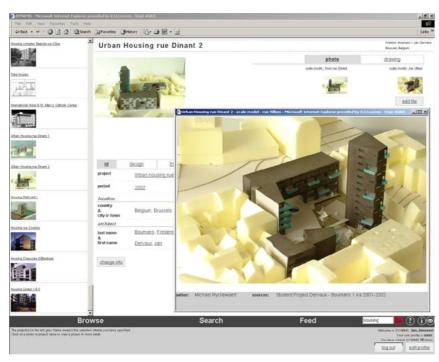
FIG. 4: Urban housing project designed by Frederic Boumans & Jan Dervaux

3.6.2 Subjects and assignment

Four architects—two junior and two expert designers—were invited to use DY*N*AMO during a two-hour design session. Both juniors had five years of experience as practicing architect, the seniors 13 and 19 years respectively. Although not 'world-famous' architects, the latter can be considered expert designers in that their work has attracted major design awards and/or won important competitions.

The subjects were given one of the assignments used in DY*N*AMO's baptism: they were asked to design an extension to the Architecture Department of the K.U.Leuven, which is located in a historical castle (see section 3.1.2).

3.6.3 Setting and procedure

A week before the experiment, subjects were given a demo of the prototype and a brief manual in case they wanted to 'practice' using the platform at home. The demo already triggered useful comments, primarily from the expert designers.

- According to one expert, it would be difficult to sell the idea of submitting self-designed projects to architectural firms unless the system would be open to journalists and potential clients. Apparently, this architect considered DY*N*AMO first and foremost as an excellent marketing channel. It was only afterwards, when discovering the different keys to access cases, that she seemed to appreciate its potential as design instrument.

- Her colleague immediately suggested a few keys to complement the current set. He too seemed get nervous about submitting his projects to DY*N*AMO, but came up with a proposal to solve it. By submitting only a selection of material (the main concept, a few photos, a simple plan) and mentioning the possibility to inquire further particulars at the office, architectural firms could tune what they release to the type of inquirer (student, journalist, competitor).

During the actual design session, the architects could go about the task as they preferred. After two hours, they were supposed to come up with a general concept for the optimization and extension of the West wing of the castle. The session was videotaped (see Fig. 5) and a log file recorded the DY*N*AMO consultations. Upon completion of the session, subjects were given a questionnaire asking their opinion about several aspects of the prototype. From the four subjects, three made effective use of the platform during the design session and

completed the questionnaire. Number four found designing in the presence of a camera too stressful and quit the session after one hour.

FIG. 5: Expert designer using DYNAMO during a two-hour design session.

3.7 Across architecture schools

3.7.1 Focus

As already mentioned, DYNAMO has been conceived as an (inter-)active workhouse to stimulate and support several modes of interaction. One of these modes, the interaction between (student) designers in different contexts, was the focus of a two-year project launched in Fall 2001 with support from the Flemish Ministry of Education. The project aimed at exploring DYNAMO's potential to share and exchange material on interesting cases with students and teachers in other architecture schools. To this end, the platform was introduced in the architectural program at the Hogeschool voor Wetenschap & Kunst (Institute for Higher Education in the Sciences & the Arts, henceforth referred to as W&K) in Brussels (Dierckx et al. 2002).

3.7.2 Subjects and assignments

Since DY*N*AMO was introduced simultaneously in three years of the architectural curriculum, the project involved three different groups of architecture students—about 50 second year students, 12 exchange students from the fourth year, and another 50 from the fifth year—along with their respective teachers. The second years worked in four- to six-person teams, the exchange students in pairs and the fifth years in groups of three. Two part-time assistants were especially appointed for the project.

In every student group, DY*N*AMO's introduction fit in with a specific assignment.

1. In order to enhance integration with the design studio, the second year course on *Computer-Aided Architectural Design/representation techniques* asked students to study in depth an exemplary house and build a 3D representation of it.

2. Within the context of the history course *Introduction to Belgian Architecture*, the fourth year Erasmus students had to analyze various pavilions of the World Exposition of 1958 in Brussels.

3. The *Construction* course in the fifth year required students to thoroughly analyze a building of their choice and present the results using diverse multimedia techniques.

3.7.3 Setting and Procedure

In order to prepare the second year assignment, the assistants collected and submitted to DY*N*AMO the basic data on the houses to be analyzed. This digitally available information enabled students to embark on the building analysis immediately. In the first phase, each group was expected to analyze a specific house in terms of concept, context, construction, philosophy and Zeitgeist, etc., and to represent the project in 3D with both physical and computer models. After an intermediate review, students had to compare the models, discover relations or contrasts, and study in depth one strong aspect of the project. The exercise concluded with a second review to focus on the interpretation of the aspect and to highlight cross-group results (Fig. 6). Upon completion, the computer models made by the students were added to DY*N*AMO.

The fourth year students analyzed various World Expo pavilions, including data about the architect, theoretical concept of the pavilion, 'Zeitgeist', functionality and spatial composition. Unlike for the second year, the assistants did not provide in advance material via DY*N*AMO, yet assisted students in preparing their collected material for submission to the platform.

Finally, in the fifth year, students investigated a building from three points of view: the evolution in material technology, subunits in the construction, and constructive typologies. The results were presented using diverse multimedia techniques. An exemplary selection of these results was added to the platform by the assistants, so that as reference for years to come.

FIG. 6: Final presentation of the housing analysis at the W&K (Photo: Martijn Stellingwerff)

3.8 Into the design firm

3.8.1 Focus

With an eye to further investigating the potential usability of DY*N*AMO for design practice, several design offices were invited to use the platform throughout all stages of the design process. DY*N*AMO's first confrontation with practitioners (see section 3.6) had pointed out the need to test the platform's efficiency and effectiveness for practice during a longer period of time. This long-term test, which started in August 2002, aimed at finding out to what extent DY*N*AMO can help integrate life-long learning and continuing education into the daily activities of design practice.

3.8.2 Subjects and assignment

Five architects from three different design firms accepted our invitation to participate in a long-term experiment. The firms differ considerably in terms of size, organisation, location, and project types.

The subjects did not receive any special assignment, but could use the platform in their own design projects whenever they felt like.

3.8.3 Setting and Procedure

The experiment started with giving subjects a demo of the prototype and a brief manual. A DYNAMO help desk was set up to assist with using the tool, and subjects were asked for feedback every six months.

The first call for feedback, six months after the introduction, was answered all in all by one subject. To make matters worse, the respondent had not been able to really use the platform because of technical problems: "*Seems an interesting system, yet I'd like to be able to try it out. This doesn't really succeed due to no connection or way too low speed.*"

4. LEARNING FROM EXPERIENCE

Having run through a 'case base' of eight quite different DYNAMO experiments, this section compares and confronts their major findings, and synthesizes the lessons learned from them. For besides the valuable feedback directly related to the prototype, these experiments have generated more general insights regarding tool support for design and design education, which transcend the realm of DYNAMO as such. For the sake of clarity, the main findings of this longitudinal study are grouped in three categories—users, uses, and usefulness.

4.1 Users

A digital library without users is a failure, however good its technology and its contents (Van House, 2003). The concept of the "*library without walls*" suggests that digitization will lead to seamlessness. Yet, many digital libraries are reported to encounter substantial boundaries (Marshall, 2003) in reaching their target audience. These boundaries are obviously less tangible than those encountered by traditional libraries, but therefore not less real. To what extent has DYNAMO been successful in establishing a community of users? And what boundaries did it encounter in trying to do so?

4.1.1 Students

As far as the students are concerned, the fraction who did use the platform fluctuates from 73% of the participants at the time of DYNAMO's baptism, over 38% and 59% on its excursions to Norway and Scotland respectively, to more than 90% in its most recent educational applications (see Table 1). Early attempts to explain these differences in student involvement revealed private access to or prior knowledge of computer technology to have little influence, thus suggesting the platform to be fairly 'democratic'. Instead, the different percentages were attributed to differences in available time, in studio equipment, and in encouragement or enthusiasm on the part of the tutors. Another factor that received less attention so far, relates to how people decide whether to trust other people's work and to incorporate it in their own work (Van House, 2003). In a traditional library, people often take for granted the trustworthiness of information based on the knowledge of its institution. In a digital library like DYNAMO, however, assessing the credibility of information becomes much more complex. DYNAMO contains content, technology, and functionality, all of which teachers and students must be willing to trust if they are to rely on it as a source of information in their studio or course, or to incorporate its content in their design, analysis or paper. While no man is a prophet in his own country, DYNAMO seems to have less difficulty to win people's trust 'at home' than abroad, even in the networked and globalized world of today. Since its Norwegian and Scottish excursion, architecture schools in many other countries know about DYNAMO and its free availability for use in architectural education, and yet hardly any of them has taken advantage of this opportunity so far. (Interestingly, the proverbial exception to this rule is a school in Bangladesh.)

4.1.2 Professionals

As to the users in architectural design practice, the picture is less sharp and above all less optimistic. At first sight, the outcome of "Destination: Practice" seemed rather promising in that three of the four participants effectively used DYNAMO, and quite enthusiastically at that. However, as the provisional results of 'Into the design firm' show, laboratory studies give only glimpses of authentic environments (Marchionini et al., 2003). Again, we could put part of the blame on (lack of) time, equipment, and trust, yet the problem may be more fundamental here. According to Vicky O'Day and Bonnie Nardi, "*Some of the major technology failures came about because too little time was spent clarifying motivations and ensuring that the policies around technology use were consistent with local values*" (2003). For instance, issues of privacy and originality, which are of utmost importance in a creative profession as architectural design, are at odds with DYNAMO's 'raison d'être',

which is to share design experience. Philip Agre therefore warns unwary designers of digital libraries for the "*trap of inventing a new world*": the persuasion that they can use technology to impose entirely new patterns of activities on their users. "*After all,*" Agre admits, "*the purpose of design is innovation, and true technical innovation is impossible unless the users change their habits.*" Yet, existing patterns of activity are usually shaped by many forces beyond technology, which designers may choose to amplify yet probably cannot create anew (Agre, 2003). Whether we have fallen into this trap indeed, remains to be seen, yet building DY*N*AMO has definitely proven to be much easier than building a community of users in architectural design practice.

TABLE 1: User participation and response

% of participants that	Baptism of fire	Norwegian Erasmus	Beyond architecture	Beyond the studio	3 birds with 1 stone	Destination: practice
used DYNAMO	73%	38%	59%	88%	93%	75%
used it more than once	46%	8%	15%	78%	(not available)	75%
felt encouraged to use it	15%	(not available)	(not available)	78%	74%	(not applicable)
completed the questionnaire	41%	26%	(not applicable)	88%	44%	75%

4.1.3 User appreciation

Across the various experiments, those subjects who did use the platform were surprisingly enthusiastic despite its obvious prototype nature. Both students and professionals above all appreciated the possibility to select projects by architectural features (concept, aspects of form and space, function, etc.) and the day and night on-line accessibility—two qualities traditional libraries tend to lack. Students seemed also attracted by the possibility to share material with others and by the storage of information in a single place, which makes searching easy and quick and allows for comparison across projects.

Weaknesses mentioned include the still limited number of projects available, and the varying quality of photos and plans. At DY*N*AMO's baptism, no less than 68% of the respondents complained about the obvious fact that you need a computer to consult it (Heylighen and Neuckermans, 2001a). Yet, in later experiments, this complaint disappeared completely. Some students would appreciate more attention for details, others got frustrated by the password-controlled access, the inability to alter material after submission, or the fact that "you always need to press the SUBMIT button" instead of ENTER to launch a search (Heylighen et al., 2002). One practitioner seemed disappointed by the fact that most projects available are well-known and thus not very surprising.

In some experiments, participants were asked to rate specific aspects of DY*N*AMO on a five-point scale (ranging from very poor over neutral to very good). The mean scores of their ratings are listed in Table 2. Across the board, users seemed satisfied with the choice of cases, selection criteria, ease of use, and look and language of the interface. Some were even very positive about the help contents and ease of learning, indicating that they had to make little investment in learning to use the platform effectively. Only the program speed and case content were judged neutral. While the former could be dismissed as a (proto)typical teething problem, the latter may be more alarming, as the effective performance of a case-based design tool is fundamentally determined by the content of its case base. At this point, DY*N*AMO's case base looks very much like a patchwork, each patch reflecting another experiment. Instead of starting from a pre-existing collection, the cases included so far have been identified and acquired ad-hoc, mostly in relation to a specific experiment. Libraries and museums feature next to restaurants, urban housing projects, and World Expo pavilions, not hindered (or backed) by any form of coherence. While some may experience this lack of coherence, of an overall theme in the case base as a DY*N*AMO's Achilles' heel, others appreciate the opportunities for cross-fertilization and innovative design ideas.

TABLE 2: Formal appreciation of specific DYNAMO aspects on a five-point scale (very poor, poor, neutral, good, very good)

	Baptism of fire	Norwegian Erasmus	Beyond the studio	3 birds with 1 stone	Destination: practice
Case choice	good	neutral	good	good	good
Case content	neutral	neutral	neutral	neutral	neutral
Selection criteria	good	neutral	good	neutral	good
Interface	good	neutral	good	neutral	good
Language used	good	good	good	good	good
Ease of learning	neutral	good	good	neutral	very good
Ease of use	good	good	neutral	neutral	good
Speed	neutral	neutral	neutral	neutral	good
Help contents	good	good	neutral	good	very good

4.2 Uses

Having formed an idea of DY*N*AMO's user population, the following two questions are: how (in what way) and why (for what purpose) is the platform used?

4.2.1 Free-riding

In principle, we expected users to consult DY*N*AMO's case base, but also to (inter-)actively participate in feeding it, be it by adding, supplementing or commenting on projects. Yet, apart from students submitting an obligatory 'paper' or analysis, hardly any participant exploited the opportunities for (inter-)action. Perhaps a good term to characterize this use is 'free-ridership' (Agre, 2003): users who do not participate in contributing to developing DY*N*AMO's content will nonetheless benefit from it. In the majority of the experiments, this may be partially ascribed to lack of time. Another reason may relate to the submission procedure, which users seemed to find rather complex at first. In general, making material available to others takes time, effort, and sometimes specific skills (Van House, 2003). Especially the articulation of appropriate metadata, which are key to identifying inter-project relationships, is far from trivial a task. Moreover, as already mentioned above, making material available seems inconsistent with the habits and priorities in architectural design practice. Professional architects turned out to be highly sceptic about sharing information on their own projects with other platform users, anxious to give away the secret of their success. (Interestingly, scientists are getting equally nervous about the implications of making available the data underlying their analyses, be it perhaps for slightly different reasons: they fear their data to be used by people with other interests, training, or expertise than theirs, or to allow critics to redo or refute their work (Van House, 2003).) Paraphrasing Nancy Van House, the distributed nature of knowledge work like architectural design means that architects are continually sharing work, whether with colleagues, team members, contractors, or impersonally through publication. But this sharing generally unfolds within social, organizational, and professional boundaries that help ensure appropriate use and reciprocity. Digital libraries such as DY*N*AMO hold the risk of decontextualizing information and making it more readily available outside the boundaries within which it was produced (Van House, 2003). If practitioners are not willing to share their knowledge, insights, and expertise across these boundaries, this may become a heavy burden on DY*N*AMO's future.

4.2.2 Not only during design

Across the board, students appreciated DY*N*AMO's support for exploring a design assignment and generating concepts, yet remained neutral about its support in further developing concepts. Practitioners, for their part, found the tool useful during exploration and concept development, yet less so during concept generation. Within the group of practitioners, however, protocol analysis revealed some interesting differences between novices and experts. While novice designers tend to scan the case base for inspiration on interesting concepts, experts rather try to project their own concepts onto the cases available. In a comparative study by Stiers and van Beuningen (2002), the novice under consideration did not consult DY*N*AMO because he was looking for anything in

particular, but to get inspired by concepts in the case base. It is these concepts that structured the way he thought about his design task. By contrast, the expert explicitly looked for concepts related to his design ideas. His search was more structured in that he tried to match his own concepts with those in the case base. That is not to say that tools like DY*N*AMO could not serve experts as source of inspiration. In fact, the expert involved in the study could very well imagine himself browsing through the case base independently of any specific design task, just by way of loading up his conceptual battery. He seemed to consider DY*N*AMO an excellent 'artificial fertilizer' that can support and improve design without necessarily being used *during* the design process, let alone the conceptual stage thereof.

Perhaps this suggestion to consult the platform *outside* the design process should not come as a surprise. As already mentioned, a major drawback of DY*N*AMO seems to be its separateness from the architect's actual design environment. For user friendly as Web browsers may be, they are not particularly compatible with architects' designerly way of working, especially not in the conceptual stage. Analysis of the videotapes (section 3.6) clearly revealed the gap between DY*N*AMO on the one hand and the designer's paper and pencil on the other hand (see Fig. 5). In order to consult the case base during design, the architect must first realise that previous cases may provide useful information, try to find relevant cases in DY*N*AMO (that is: switch to the browser, type in the URL, specify one or more selection criteria, screen the cases that meet these criteria and pick out the relevant information), and finally carry the information back to the paper and pencil environment. Each of these steps interrupts the design process considerably. In order to avoid such interruption and fully integrate case consultation with the very act of designing, cases should be directly accessible from *within* the architect's design environment. Further development therefore includes implementing a scenario for case retrieval that is interwoven with architects' activities during design (see also section 2) (Heylighen and Segers, 2002). More in general, this scenario challenges the model of a "user" first conceiving of an information need and then going out and getting that information. As other researchers have pointed out, "*the search-and-retrieval model is too simplistic, rational, and mechanical to describe the dynamics of how people, groups, and infrastructure come together as resources*" (Star et al., 2003). Information is not a static product that is "out there" waiting to be found, but rather a construct of particular situations at specific points in time.

4.3 Usefulness

Whether DY*N*AMO is used within or outside the design process, strictly speaking the only thing that matters is the effect of this use. Does using DY*N*AMO make any difference?

4.3.1 Design

In terms of DY*N*AMO's impact on the quality of what architects design, it is far too early to even start thinking of drawing conclusions. Nevertheless, various experiments with student architects provide every reason for optimism. The design teachers of the *Urban housing* studio (section 3.5), for instance, had the impression that students got a hold over the assignment more fluently (Heylighen et al., 2003b). In the *Building reuse* studio (section 3.1), detailed analysis of students' results showed that using the platform is positively related to the overall quality of their design, as well as to specific aspects such as concept, form, function, reuse strategy and degree of creativity (Heylighen and Verstijnen, 2003). The latter finding is especially important, as it suggests that users of tools like DY*N*AMO do not run the risk of design fixation. Quite the contrary seems to be the case. Note, however, that the positive effects of using DY*N*AMO considerably differed depending on the assignment students had chosen (public library or architecture school). The most plausible explanation for this difference lies in the content of the case base, which, at the time of the experiment, contained relatively more and richer cases that were relevant for the library assignment. This hypothesis is confirmed by studies on the role of analogy in design, which show student architects to draw knowledge from design cases, but only if they relate directly to their design task (Leclercq and Heylighen, 2002).

4.3.2 Building analysis

In addition to pure design tasks, DY*N*AMO has been (and is being) employed in the context of building analysis. Although not explicitly conceived for this purpose, various experiments have revealed the platform to be an excellent vehicle for exchanging material and insights within (part of) an architecture school, i.e. among student architects and their teachers. Providing students with basic project documentation saves them time-consuming search and scan work, so that more time and energy can be spent on the analysis itself (section 3.7). Using a template or predefined format forces students to shift attention from the form, c.q. layout, to the content of the

analysis (section 3.4). Last but not least, students seem extra motivated by the fact that their work serves a useful purpose rather than ending up on their teacher's shelf: "*Really great to see afterwards what you've realised: something on the Web!*" Yet, also in the context of building analysis it is too early to draw conclusions about the impact of using DYNAMO. Applications like these can only be assessed as they are offered repeatedly, so that students can profit from an accumulation of analyses and references. Therefore perhaps the most significant result of these experiments is that, as we write this article, the tutor of *Architectonic Composition and Program Studies* (section 3.4) is using DYNAMO for the fourth year in a row. These repetitions should allow to better exploit the platform's capacity to share analyses among students, and to support them in building analysis and ultimately in design.

4.3.3 Curriculum integration

Even less foreseen than DYNAMO's use for building analysis, was its application throughout an entire architectural curriculum (section 3.5). The overall objective of this application, to create a synergy among various curriculum components, has definitely been reached at least in part. Housing projects analyzed in the seminar largely overlap with projects used to exemplify the assignment of the *Urban housing* studio. Giving feedback on the seminar work at the start of the studio obviously reinforced this link. The link with *Architectural theory* is less evident, probably because the course relies mainly on projects with a deep theoretical significance. These projects, often belonging to the canon of architectural history, rarely coincide with those used in the seminar and studio. According to van Schaik, the canon of great works is not about spatial knowledge: it is a learned body of works described in a special language unrelated to the everyday experience of people (van Schaik, 2003), and thus probably less appropriate to support the seminar and studio assignments. Moreover, given that architectural theorists characterize projects by tendencies and movements (as opposed to the other categories in DYNAMO, which are conceived from a designer's point of view), the material for this course was structured differently from the start. Therefore, several years after its first implementation, DYNAMO was supplemented, albeit reluctantly, with a 'theory' window in order to allow for users to approach cases through theoretical tendencies or movements.

As to the objective to improve students' 'architectural culture', the impact of using the platform is difficult to measure. Nevertheless, students involved in all three experiments undoubtedly got acquainted with a more substantial set of architectural projects, in quantitative, but especially in qualitative terms: the platform offers students more and better project material than used to be the case before. Moreover, they can study projects more in-depth, at their own pace and supported by their colleagues' analyses and interpretations. The cumulative effect, in the context of the didactic experiments as well as in other parts of the curriculum, is evident. Weaknesses remain the need for selection and filtering of the material, as in many digital libraries without librarian, and for sustaining the efforts to feed the platform now the pilot project is finished.

5. SUMMARY AND CONCLUSION

Inspired by the Theory of Dynamic Memory, DYNAMO was originally conceived as an (inter-)active workhouse, where student and professional architects are stimulated and supported to learn from past (design) experience. Five years after its first implementation as a working prototype, this paper has looked back on how it was and is brought into action in different contexts—within, across and beyond architecture schools—and with various purposes—whether or not in line with our original intentions. These experiments were first of all instrumental in the step-wise development and refinement of the prototype. They generated a considerable amount of feedback that fundamentally shaped the subsequent versions of the platform. On a more general level, this longitudinal study has produced valuable insights regarding tool support for design and design education, which transcend the realm of DYNAMO as such.

At the end of the day, DYNAMO's role has gradually evolved from an information and communication platform to support students and professional architects during design into an instrument for improving curriculum integration through a process of cumulative knowledge development. This new notion of Integrating Curricula Technology (ICT) seems to fit DYNAMO as a glove and has been successful in triggering a new funding cycle. However, apparent success may be short-lived. The model of DYNAMO as ICT 'new style' (an educational instrument) used to guide the pilot project, is significantly different from and even in conflict with the model of DYNAMO as a resource for journalists and potential clients (a marketing instrument) suggested by a professional architect, both of which differ from the original concept of DYNAMO as a collective memory to exchange design experience between students and professionals across different contexts and levels of expertise

(a design instrument). Judging from experiences with other digital libraries, "*In terms of facilitating projectwide coordination strategies and developing some sense of overall identity, contradictions emanating from differing objectives are profoundly problematic*" (Spasser, 2003). In terms of vision and hope, DY*N*AMO is still a design support tool, yet drawing conclusions about its ultimate form or successful integration—not of an architectural curriculum, but into design practice—is impossible. Will it transform into a lowest-common-denominator solution—the worst case scenario—or will it be able to hold on to this high-level vision coupled with systematic and iterative assessments? (Marchionini et al., 2003) As of this writing, DY*N*AMO is further evolving and new ideas about its further development are emerging (but still too embryonic to share). Moreover, as a new entry into design practice and education, DY*N*AMO is not only affected by but potentially changes existing processes and relations. While it is probably naïve to expect these changes to affect the architects of today, putting our hopes on the architects of tomorrow may be slightly less so. As more and more students get familiar with consulting but also feeding tools like DY*N*AMO, our hope is that, when they step into practice, at least some of them will continue doing so. Therefore, until further notice, DY*N*AMO continues its efforts to challenge taken-for-granted practices in the design profession, to make visible the invisible boundaries of design knowledge exchange, and to highlight the mechanisms of trust and credibility, all of which are central to the creation and use of (design) knowledge (Van House et al., 2003).

6. ACKNOWLEDGEMENTS

7. REFERENCES

Agre P. (2003). Information and Institutional Change: The Case of Digital Libraries, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 219-240.

Casteleyn B. (2000). *Conceptvorming in het architectuurontwerpen. Een kennistheoretische en experimentele verkenning*, Master's thesis, K.U.Leuven, Dept. ASRO, Leuven (Belgium).

Cross N. (1982). Designerly ways of knowing, *Design Studies*, Vol. 3, No. 4, 221-227.

Duval E. (1999). An Open Infrastructure for Learning – the ARIADNE project: Share and reuse without boundaries, *Proceedings of ENABLE99: Enabling Network-Based Learning*, 144-151.

Dierckx, T., Stellingwerff, M. and Verbeke, J. (2002). Relating to the 'real'. Theories for and Experiences with Educational Database Systems, *Connecting the Real and the Virtual – design e-ducation*, eCAADe, Warsaw (Poland), 80-87.

Heylighen A. (2003). A maintenance contract for the architect's degree. Concept, materialisation and post-occupancy, *Writings in Architectural Education* (Harder E., editor), Transactions on architectural education, No. 15, EAAE/AEEA, 134-147.

Heylighen A. and Neuckermans H. (2000). DYNAMO – Dynamic Architectural Memory On-line, *Educational Technology and Society*, Vol. 3, No. 2, 86-95.

Heylighen A. and Neuckermans H. (2001a). Baptism of fire of a Web-based design assistant, *Computer Aided Architectural Design Futures 2001* (De Vries B., Van Leeuwen J. and Achten H., editors), Kluwer Academic, Dordrecht (The Netherlands), 111-124.

Heylighen A. and Neuckermans H. (2001b). Destination: practice. Towards a maintenance contract for the architect's degree, *Reinventing the Discourse* (Jabi W., editor), ACADIA, Buffalo (NY), 90-99.

Heylighen A. and Neuckermans H. (2003). (Learning from Experience)² - Promises, Problems and Side-effects of Case-Based Reasoning in Architectural Design, *International Journal of Architectural Computing*, Issue 01, Vol. 01, 60-71.

Heylighen A., Neuckermans H. and Morisse P. (2003a). What You See Is What You Get, *IEEE Multimedia*, Vol. 10, No. 3, 48-56.

Heylighen A., Ryckewaert M. and Neuckermans H. (2003b). Yet another paper about integration?, *Digital Design*, eCAADe, Graz (Austria), 17-20.

Heylighen A. and Segers N. (2003). Look who's suggesting, *International Journal of Design Computing*, Vol. 6.

Heylighen A., Schreurs J. and Neuckermans H. (2002). ENTER instead of SUBMIT. What student-designers (dis)like about information technology, *DesignNet - Knowledge e Information Management per il design* (Ciuccarelli P. and Perla Innocenti P., editors), Edizioni POLI.design, Milano (Italy), 171-182.

Heylighen A. and Verstijnen I.M. (2003). Close encounters of the architectural kind, *Design Studies*, Vol. 24, No. 4, 313-326.

Heynen H. and Loeckx A. (2003). Constructing a memory for architecture. Two didactical tools in Leuven, *Four Faces - The Dynamics of Architectural Knowledge*, 20th EAAE Conference Book of Proceedings, EAAE, Stockholm-Helsinki, pp.67-70

Kolodner J.L. (1993). *Case-based Reasoning*, Morgan Kaufman, San Mateo (Ca).

Leclercq, P. and Heylighen, A. (2002). 5,8 analogies per hour. A designer's view on analogical reasoning, *Artificial Intelligence in Design '02* (Gero J.S., editor), Kluwer Academic, Dordrecht (The Netherlands), 285-303.

Marchionini G., Plaisant C. and Komlodi A. (2003). The People in Digital Libraries: Multifaceted Approaches to Assessing Needs and Impact, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 119-160.

Marshall C.C. (2003). Finding the Boundaries of the Library without Walls, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 43-64.

Morisse P. (2001). *Visuele sleutels voor Dynamic Architectural Memory On-line (DYNAMO)*, Master's thesis, K.U.Leuven, Dept. ASRO, Leuven (Belgium).

Neuckermans H., Heylighen A. and Morisse P. (2002). Visual keys to architectural design, *CAADRIA 2002* (Eshaq A.R.M. et al., editors), Prentice Hall, Sealngor (Malaysia) 175-182.

O'Day V.L. and Nardi B.A. (2003). An Ecological Perspective on Digital Libraries, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 65-84.

Riesbeck C.K. and Schank R.C. (1989). *Inside Case-based Reasoning*, Lawrence Erlbaum, Hillsdale (NJ).

Schank R.C. (1982). *Dynamic Memory – A Theory of Reminding and Learning in Computers and People*, Cambridge University Press, Cambridge (Mass).

Schön D. (1983). *The Reflective practitioner. How Professionals think in action*, Basic Books, New York (NY).

Segers R. (1998). *Prototype van een interactieve case-base voor architectuur, geïllustreerd met woningen op helling*, Master's thesis, K.U.Leuven, Dept. ASRO, Leuven (Belgium).

Spasser M. A. (2003). The Flora of North America Project: Making the Case [Study] for Social Realist Theory, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 297-327.

Star S. L., Bowker G. C. and Neumann L. J. (2003). Transparency beyond the Individual Level of Scale: Convergence between Information Artifacts and Communities of Practice, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 241-270.

Stiers J. and van Beuningen A. (2002). *Designing with DYNAMO*, unpublished paper, K.U.Leuven, Leuven (Belgium).

Van House N. A. (2003). Digital Libraries and Collaborative Knowledge Instruction, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 271-296.

Van House N. A., Peterson Bishop A. and Buttenfield B. P. (2003). Introduction: Digital Libraries as Sociotechnical Systems, *Digital Library Use. Social Practice in Design and Evaluation* (Peterson Bishop A., Van House N. A. and Buttenfield B. P., editors), The MIT Press, Cambridge (Mass), 271-296.

Van Schaik L. (2003). The Practice of Practice: practice based research in architecture, *The Practice of Practice: research in the medium of design* (van Schaik L., editor), RMIT University Press, Melbourne (Australia), 12-19.