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On-line critiques in collaborative design studio

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Abstract In this study, the Design Collaboration Model (DCM) was developed to provide a medium for the on-line collaboration of the design courses. The model was based on the situated and reflective practice characteristics of the design process. The segmentation method was used to analyse the design process observed both in the design diaries and the redline files that were composed of the problem domain and the design strategies. In the problem domain, it was observed that high emphasis was given to the design abstractions in the level of details of a space or sub-space. Also, the critics were more interested in the solution space than the problem space. As a design strategy, rejecting a solution was more practiced than proposing alternative solutions. Since the performance score of the students was highly correlated to the number of segments in critiques, it is concluded that quality rather than quantity of critiques determine the success level of proposed design solutions.

Keywords Collaborative design · Critiques · Design process · Design strategy

Introduction

Design education involves a highly interactive process among students and instructors while providing alternative design solutions. As Dong (2006) stated, the core design skills and knowledge are transferable throughout design domains. The reflection of ideas on

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design drafts formulates and improves the solutions of design problems. Integration of computer mediated collaboration in design education broadens a student's point of view by enhancing the ability to discuss and evaluate various design concepts or ideas. Collaborative Design Studios (CDS) are developed both in professional practice and design education for enabling the participants to work together in a computer mediated network regardless of time and location limitations. Earlier studies on CDS were based on unstructured design collaboration to promote open interaction for the educational studio (Craig and Zimring 2000; Zimring et al. 2001). However, well-organised on-line space is more effective and usable than an unstructured one (Cicognani 2001). Besides Chiu (1998) observed that structured collaboration in design studios stimulate effective actions of students, enhance the performance of collaboration and help the development of solutions.

In CDS, the tools and methods determine the structure of collaboration space. Asynchronous and/or synchronous tools can be used to conduct communication and collaboration. The tools for communication should be chosen according to the collaborator's profile, design brief and technological potential (Cheng and Kvan 2000). It is necessary to provide guidelines for creating team exercises, monitoring team process and developing assessment methods to incorporate teamwork in learning environments (Swigger et al. 2003). The development of the course material, the training and adaptation for participating students and instructors should be considered as well as tools and methods. Course planning for a design course is a complex process when it is to be implemented on the web (Sagun et al. 2001). As Kvan et al. (1999) claimed, successful design collaboration in a computer-mediated environment is achieved by simulating the conditions found in face-to-face critiques.

In this study, a Design Collaboration Model (DCM) is developed as a framework for on-line collaboration of two design courses based on the issues of situatedness (Fischer and Ostwald 2002; Clancey 1997) and reflective practice (Schon 1987). A structured CDS consisting of an information and collaboration web site is constructed and implemented to identify the content of the critiques and how the information is transferred through critiques in an on-line CDS. Moreover, the level of participation of students and instructors in critiques and their emphasis on design issues related to the problem domain and the design strategies were investigated.

Content of critiques in design process

The design process cannot be simply grasped by any methodology, but it can be assessed through the content of critiques on design representations (Demirbas and Demirkan 2003; Uluoglu 2000). Dong (2006) described the representations of design ideas in two categories as the visual forms and the linguistic forms. In design studios, the students represent their design ideas through sketches and discuss their design solutions with their instructors. Sketches as the external representations provide a link between the actual world and the mental world of the designer (Demirkan 2005; Senyapili and Basa 2006). Positive or negative critiques of the instructors on the design representations enable students to observe and assess their design projects. The design critiques help the students to develop their design projects by pointing out the efficient and useful solutions as well as types, levels and location of the inconsistencies in the design. In addition, the critiques of the other design students can be effective in design development. As Cheng (2004) stated, giving critiques to each other's work enable students to see the design project through the eyes of the others. Although the content of information and knowledge communicated in

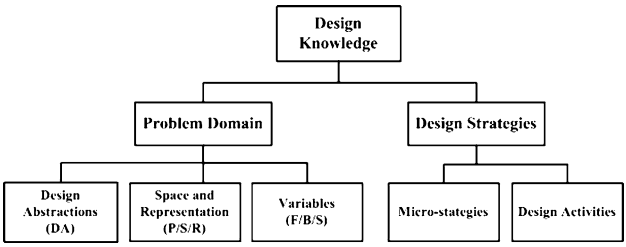

Fig. 1 Categorisation of design knowledge

design critiques are based on the class level and experience of the students, the instructors may be oriented with the questions of the participatory students pointing out the neglected issues.

The conceptual structure of the design studio determines the content of a design critique both in quantitative and qualitative terms. Moreover as Uluoglu (2000) stated ''the content that fills in the structure … differs according to individuals; hence, content is the quality of knowledge, which makes it a personal phenomenon (p. 45)''. In this study, the content of knowledge that is exchanged through the critiques are categorised and analysed related to the problem domain and the design strategies (Fig. 1).

Design knowledge in the problem domain can be related to different levels of design abstractions, spaces and variables. During information exchange, critics refer to different levels of design abstractions for space, sub-spaces, objects and their interactions (Gero and Mc Neill 1998). Moreover, these critics' comments either refer to design problem (P) or solution spaces (S) as explained by Maher and Tang (2003). Also, transferred knowledge can be oriented towards the functional (F), behavioural (B) and structural (S) aspects of design.

In terms of design strategies, Gero and McNeill (1998) stated that either the critic analyse a solution, propose a solution or refer to explicit strategies. These were named as micro-strategies that are a sub-category of design strategies. Besides, direct reference to high level or low level design activities can be observed during design development as design strategies (Vera et al. 1998).

CDS within the framework of design collaboration model

The design process has a reflective nature in the sense that the students develop their design by reflecting on their new ideas and solutions in each step as the result of the critiques (Demirbas and Demirkan 2003; Schon 1987; Sagun and Demirkan 2003). Since there is a development in each step based on the previous critiques, a design process can be identified as a series of situated acts. In problem solving process, the students should satisfy the requirements of the new course without neglecting the requirements of the other courses. Also, the appropriate dimension, materials and circulation routes should be reconsidered in the design.

The aim of the case study is to formulate a structured framework for the collaboration of design courses through the Internet. The study examines the following issues:

- How is information transferred through the critiques in a CDS?
- What is the content of critiques and level of collaboration of the students and the instructors in a CDS conducted through the Internet?

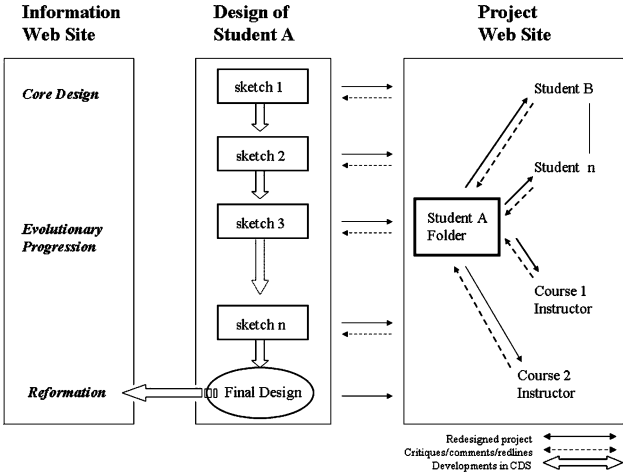

Fig. 2 DCM model

- What are the design issues related to the problem domain and the design strategies that collaborators emphasise during the critique sessions?

In this study, a collaboration process was conducted at the conceptual design level through the use of an asynchronous communication system among students and instructors. DCM was constructed based on the concepts of situatedness and reflective practice, as the two basic concepts in design education. The DCM has two web sites on the Internet to fulfil the requirements of these concepts, named as the Information Web Site and the Project Web Site (Fig. 2).

Information web site

The Information Web Site constructed within the DCM is a bridge allowing access to the core design, evolutionary progression and reformation phases. It has five main sections as seen in Table 1 (Sagun 2003).

The sections named as the knowledge domain and the students constitute the core of the DCM Information Web Site that contains all the required information for the collaboration and the design studio process. The information about the collaborative design courses, their objectives and the details of the design project can be accessed through the section named as the collaborating courses. This section enables the evolutionary progression phase and there is a link to the DCM Project Web Site (www.projectgrid.com), which is the interactive collaboration site for discussing and sharing ideas in order to develop design projects. Communication of the collaborators in the evolutionary progression phase is also provided by the information documented in the communication section. The final section is the virtual design library in the reformation phase. It provides an archive for storing the useful information that can be referred in the following semesters. It includes the designs and drawings of the previous projects and a library of CDS projects that were submitted to the project site.

Table 1 DCM Information web site

Model phases	Sections	Sub-sections
Core design	Knowledge domain	CDS information
		Schedule
		Technical requirements
	Students	CDS
		Group study
		Class notes
		Student projects
		Tutorials
Evolutionary Progression	Collaborating courses	Design Studio
		Design for Disabled
		CDS project site
	Communication	Announcements
		Participants
Reformation	Virtual design library	CDS projects archive
		Course 2 design archive

Project web site

A host website (ProjectGrid) was chosen as the project web site for DCM implementation. Available collaboration characteristics, technological issues and economic constraints were considered in deciding the suitable collaboration tool. Besides, the local content such as used platform, user's base and computer configurations were analysed. Ease of use was an important factor in deciding for the web site, since it provides quick adaptation and effective use of the system.

Using the host web site (ProjectGrid), the AutoCAD drawings were converted to Drawing Web Format (DWF) to be shared by the collaborators. The redline tools provided by the CAD Viewer enabled the critics to mark the part of the drawing that they want to emphasise and write the corresponding critique. The asynchronous critiques were documented as a redline file in the host project collaboration site. The redline files and the corresponding drawings were accessible only by the authorised collaborators. A screen shot of the Web browser with a critique that is marked on the drawing can be seen in Fig 3.

Every step of the design process for each drawing was archived in the database of the web site. In the reformation phase, this archive can be used as the virtual design library for the future drawings or as the exemplary cases in the following courses (see Table 1). In the DCM information web site, this archive also is kept in the virtual design library. It provides easy access to the collaborators and also prevents the loss of information and data at the end of the subscription to the host web site.

Architectural design experiment

Design project

In this study, the students were required to redesign the project that was given in the design studio within the requirements of another design course (Design for Disabled). The design

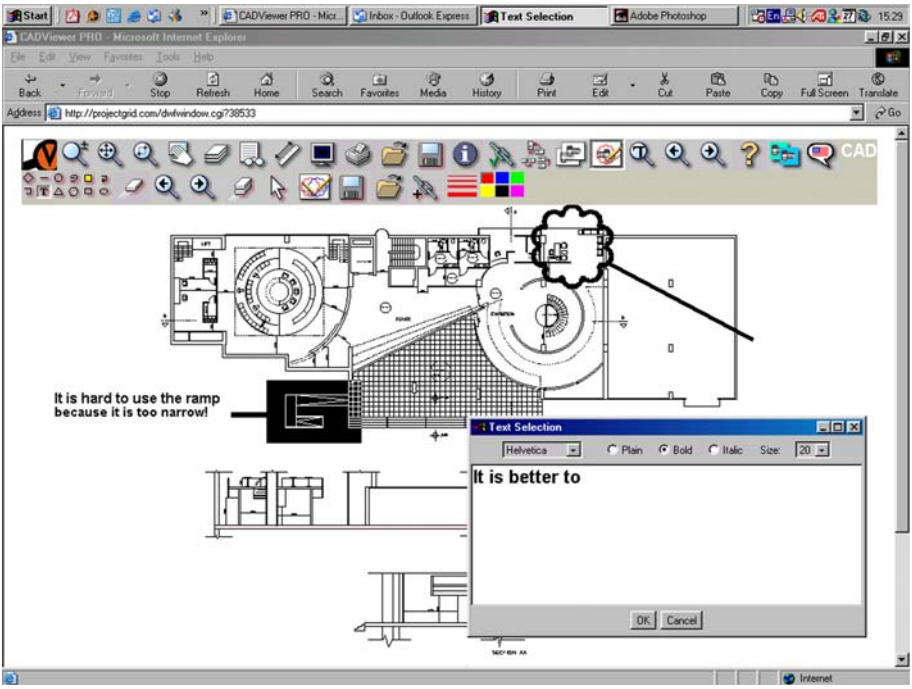

Fig. 3 An example for redline drawing

knowledge gained in both courses had to be integrated. As a result of the collaboration among the participants of the two design courses, the design solutions explored the needs and requirements of the disabled people. The design solutions generated during this collaborative process were stored in the database to be used as a reference for the reformation of the CDS and as the paradigms for the following semester courses. Consequently, the collaboration process of the two courses can be enriched and progressed in the following semesters.

Collaborators and collaboration procedure

The requirements for being a collaborator were the familiarity with a PC and a basic working knowledge of Microsoft Windows, skills in using AutoCAD, Web Browser, and sending and receiving e-mails and a minimum of 2 years design experience. At first, a pilot study was conducted with two collaboration groups. The segmentation categories and the requirements of the collaborating courses for the analysis of CDS were based on this pilot study. The study was conducted in the following semester with nine collaboration groups in 5 weeks. Each group included five people: a project designer, and two instructors and two students as critics. The critics were comprised of the third-year students of the Department of Interior Architecture and Environmental Design and the instructors of the Design Studio and Design for Disabled courses at Bilkent University.

At the beginning of the CDS, all the students and the instructors were informed that the design critiques would be given on the Internet environment. A written document was

distributed to the collaborators that explained the rules and principles of collaboration process. The collaboration process started with the registration to the web site for downloading the design files. The projects developed with the given feedbacks by the group members through the asynchronous critiques. Each week on Mondays, the students submitted their redesigned projects. Then each collaborator had a chance to give critiques to the redesigned project until the following Thursday. The given critiques were accumulated in the redline files.

Design process observed in the redline files

During the collaborative study, the given critiques were analysed by using the data in the redline files related to the problem domain and the design strategies. The issues were defined and categorised based on the critiques of the pilot study.

Segmentation

Each redline file including the comments and critiques of the team members was parsed manually into small units called segments in order to encode the analysis process. The segments were driven from a single comment of a critic on a single part of the project, guiding the student's design decisions. Usually a single comment was stated in a single sentence or phrase, but in some cases more sentences or phrases were added to clarify the statement. In that case, all the sentences and phrases pertaining to the same design issue were considered as a single segment.

Coding scheme for problem domain

The problem domain has three categories for segmentation: design abstraction, space and representation, and variables.

Design abstraction (DA)

Gero and Mc Neill (1998) categorised the design process with respect to four levels of abstraction as system, interactions, sub-systems and details. In this study, there are six abstraction levels that are denoted by the numerals 0–5 to represent the whole building (0), sub-spaces of the building (1), interaction among sub-spaces (2) and objects (3) and details of the space (4) or objects within the space (5) (see Appendix A). The objects include issues like furniture, accessories, lighting units, doors and windows in a space. The details of a space, sub-space and object include design issues of dimension, direction, location, material and construction elements. Also, the requirements for the two courses are differentiated as 'Rd' standing for the Design for Disabled course and 'Rs' for the Design Studio course. Questions or statements about the representations that can not be understood by the critics are coded as undefined (U). The nine categories and the related examples can be seen in Appendix A.

Domain space and representation (P/S/R)

The problem and solution spaces were identified in the segments of the design critiques. Since collaboration was involving asynchronous design tools, there were also comments, references or questions that were related to the representation of a design. They were involving inconsistencies or undefined parts of the drawings, such as meaningless lines that cannot be understood by the critic. Thus, the space and representation (P/S/R) group indicates whether the content of the critique is related to the design problem (P), design solution (S) or design representation (R) (see Appendix A).

Domain variables (F/B/S)

Maher and Tang (2003) defined function, behaviour and structure issues in co-evolutionary design process. In this study, the variable (F/B/S) group indicates whether the critique is related to the aspects of function (F), behaviour (B) or structure (S) of the space or objects within the space. Functional aspects include layout and functional use of space or object. The behavioural aspects are related to the use, circulation routes and obstacles. In structural aspects, the elements, details, dimension and materials used for the space or object are involved (see Appendix A).

Coding scheme for design strategies

The design strategies were analysed as micro-strategies and design activities in the redline files.

Micro-strategies

The three categories of the micro-strategies were based mainly on the system defined by Gero and Mc Neill (1998) as analyse a solution, propose a solution or refer to explicit strategies in the redline files. The category for analyse a solution includes the responses of the critics to the design solution that was submitted by the student. The second category includes the proposals of the critics for the project development. Finally, the category of the explicit strategies were involving statements or proposals that either refer to a specific requirement, knowledge or strategy (see Appendix B).

The sub-groups were determined according to the characteristics of the collaborative design process. The first two codes under analyse a solution category either refers to the justification (Js) or rejection (Rs) of the design decision of the student. If the critic warns about a missing issue (Wm) or give critiques to clarify a problem (Cu) regarding the actual future use of the designed space or object, they were coded as separate issues. Other items in coding of this group were related to the comparisons (Co) or references to the previous solutions (Rp) of the critics while stating their comments or expressing ideas during design analysis process. Moreover, the collaborators can communicate through drawings about some missing, undefined issues in the designs with questions on design concept (Qc), questions on space (Qs) and questions on objects (Qo) within the space or questions on missing and undefined design representations (Qr) in the drawings. Examples for these questions are seen in the last four code groups, under analyse a solution category in Appendix B.

The critiques related to propose a solution category were coded as three micro-strategies. In addition to the analysis of design category, it is also possible for a critic to propose a new solution or choices of new solutions for the previous solutions, missing issues or unsolved problems in design process using the redlines. The proposal may include one or more new solutions (Ps or Cs) or refer to the previous solutions (Lp) and leave the choice to the designer.

The last category, the explicit strategies can be related to an application knowledge (Rak), knowledge and requirements of the design domain (Rdk) and design strategies (Rds) discussed in the collaborating courses (Design for Disabled and Design Studio). The critics can state various design strategies (Rsk) for the improvement of design process (see Appendix B).

Design activities

The requirements of a design problem can be related to high level (HL) or low level (LL) design activities (Vera et al. 1998). HL design requirements include comments or critiques about layout (LY), circulation (CR), dimension (DM), shape and geometry (SH), construction systems (CS) and obstacles (OA) within the design space. LL design requirements include comments or critiques about the secondary issues of design such as lighting (LT), material (MT), furniture (FR), signs (SG) and accessories (AC) (see Appendix B). Undefined (U) refers to any comment or question of the critic about an unclear representation of the students. Examples of the design activity segments can be seen in Appendix B.

Design process observed in design diaries

The students were required to submit a design diary at each phase of the project that includes a brief explanation of the changes as the additions, removals or modifications that they have done on the designed space or objects.

Segmentation

The segmentation of the design diaries was focused on the intention of the student during the design process. Therefore, each segment in the design diary was driven from a single intention of the student. If a single design intention of the student was stated in more than one sentence or phrase, then all of them that were pertaining to the same intention or modification were considered as a single segment.

Coding scheme of design diaries

The coding system of the study was based on the problem requirement and the solution spaces. Maher and Tang (2003) developed a coding scheme based on the features and behaviours of both problem requirement and solution spaces for the co-evolutionary design model. In DCM coding, the problem and solution requirements were also related either to the features or behaviours of the design problem (R-fe and R-be) (See Appendix C). Features of problem requirements involved statements about specific features of the design

problem and the two collaborating courses. For instance, the modification made by a student as a result of a requirement of one of the collaborating courses was considered as R-fe. Behaviours of the problem requirements involved statements about decisions or modifications related to the behaviour of the design problem throughout the design process. Thus, any statement made related to the requirements of a previous critique can be an example for R-be.

The solution space involved statements related to the features of design solution (S-fe) and the behaviours of design solutions (S-be). A statement that explains the features of a design solution was considered as S-fe such as definitions, explanations and statements about a new item added to the design. A statement involving a development or change in design as a result of a success or failure in the behaviour of a design solution was considered as S-be, such as changes in the dimensions of a space or an object in order to provide accessibility to the designed space.

Results

Either qualitative or quantitative research methods have been traditionally used to study the interactions on the Internet (Riva and Galimberti 2002). But Sudweeks and Simoff (1998) claimed that a structured framework should use both qualitative and quantitative data to balance the strengths and weaknesses of each method. In DCM, the amount of collaboration in the design process and the frequency of interactions were discovered through the analysis of quantitative data. Besides, the qualitative data that was gathered in the redline files and the design diaries were coded and quantified for statistical analysis to explore the collaborative study.

Interpretation of quantitative data

Analysis of redline files

The redline files contained the design representations that were both in visual and linguistic forms. The total number of critiques given by the collaborators throughout the design process in 5 weeks was 96. The highest number of critiques was given in the first week of the collaborative study. In the following three weeks, the total number of given critiques was approximately the same and it was the lowest at the last week.

In order to determine the amount of collaboration of the team members, the total number of critiques was also analysed. It was found that the amount of collaboration of the students (53%) was more than the amount of the instructors (47%) of which 30% belonged to the Design for Disabled course instructor.

Then, the total number of critiques was parsed into 377 segments. As seen in Fig. 4, the total number of segments that was produced in the critiques was decreasing throughout the weeks.

The total number of segments produced by the students and instructors was also analysed. Although the students gave the highest number of critiques, it was observed that the instructors (56%) produced the highest number of segments. Among the 56% of the segments, the higher number of segments was produced by the Design for Disabled course instructor (40%). But there was no significant relationship between the instructors and the given number of critiques (2-tailed Fisher exact $p = 0.371$).

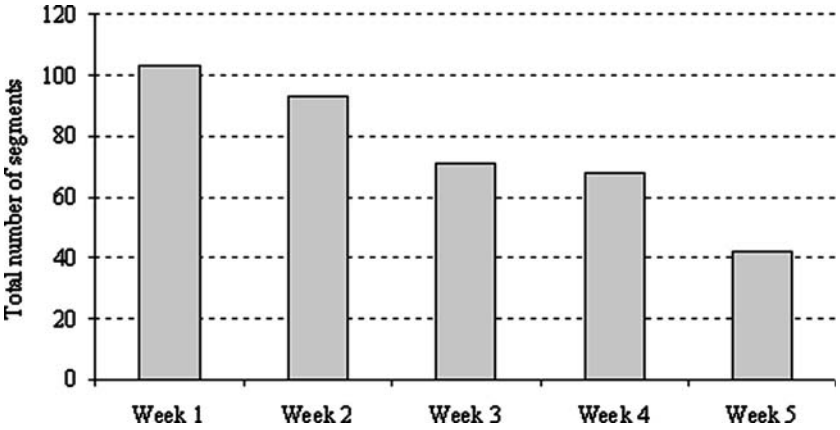

Fig. 4 Total number of redline segments in each week

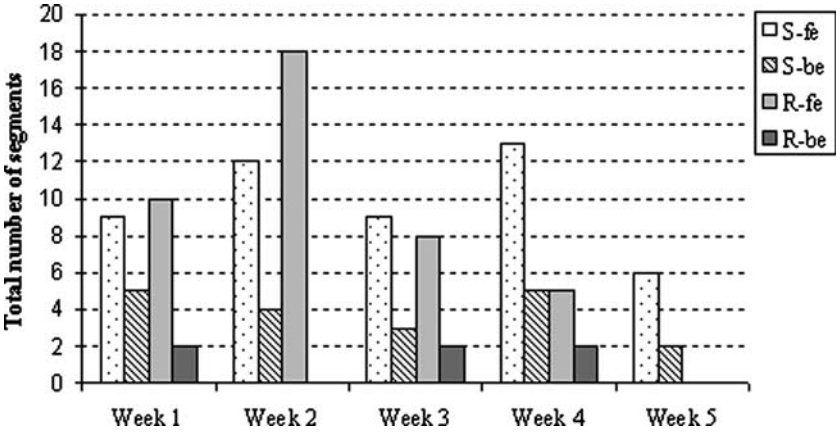

Fig. 5 Total number of segments in design diaries in each week

Analysis of design diaries

In order to observe the design representations only in the linguistic forms, the design diaries were analysed. The students submitted 34 design diaries during the CDS process. The total number of segments derived from the design diaries was 115. The weekly distribution of the features and behaviours of both problem and solution requirements in the diaries are shown in Fig. 5.

Interpretation of qualitative data

Analysis of redline files

Problem domain The analysis of data with respect to the design abstractions in problem domain category indicated that the highest percentage of the segments (27%) referred to

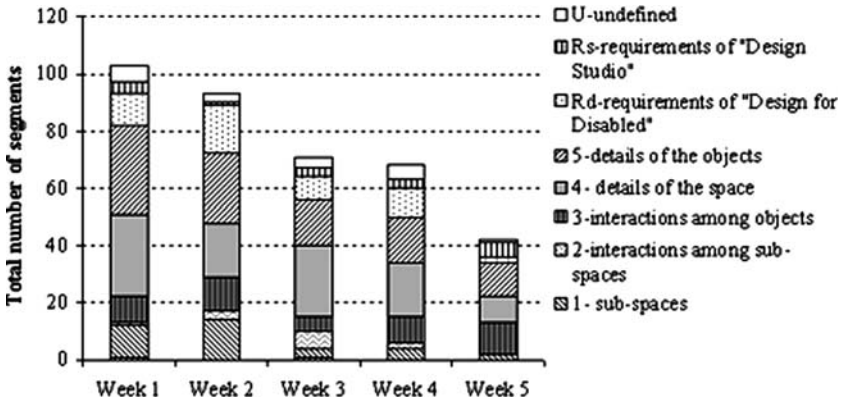

Fig. 6 Total number of design abstraction segments in each week

the details of the space and the sub-spaces (4). It was closely followed (26%) by the details of the objects within the space (5). The other important issues discussed in the critiques were related to the requirements of the Design for Disabled course (Rd) and the interactions among object (3) with 13% and 12%, respectively. The weekly distribution of the design abstractions in problem domain category can be seen in Fig. 6.

The analysis of data with respect to the second category (problem, solution and representation) of problem domain illustrated that CDS was characterised by a high proportion of references to the solution space of the problem (66%). It was followed by the problem space (23%) and representation (11%). In the redline files, the number of segments related to the solution space decreased each week as seen in Fig. 7.

The analysis of the third category, function, behaviour and structure in the problem domain, indicated that the majority of the critiques refer to the discussions on the behavioural aspects of the design domain (64%). The function and structure aspects were found to be in 24% and 12%, respectively. The analysis of the number of segments per week showed that there was a decrease only in the references to the behavioural and functional issues throughout the CDS process (Fig. 8).

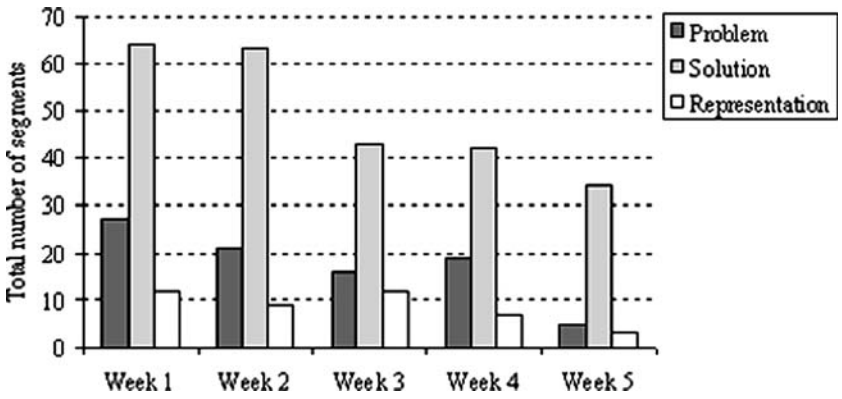

Fig. 7 Total number of domain space and representation segments in each week

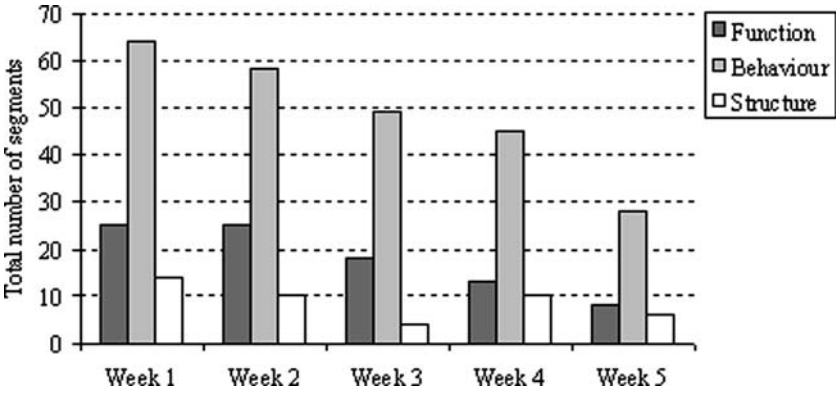

Fig. 8 Total number of design variable segments in each week

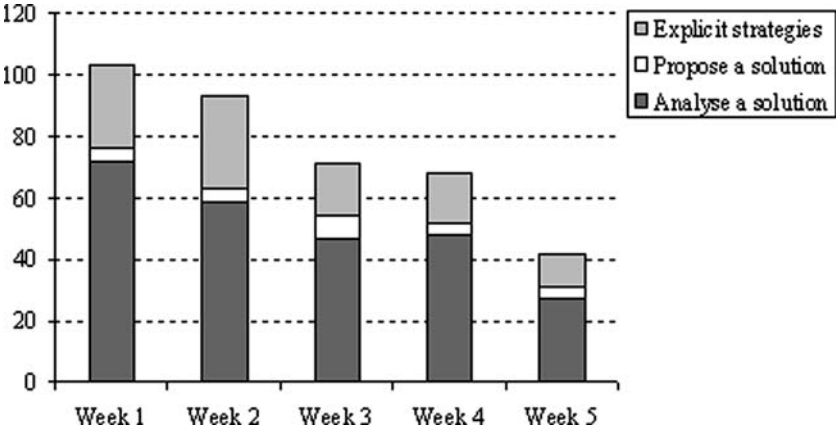

Fig. 9 Total number of design strategy segments in each week

Design strategies: When the total number of segments were analysed according to the design strategies, it was observed that the majority of the critiques were about the design solution analysis category (67%), where the proposing a solution (27%) or the explicit strategies (6%) categories were less in total. It was also observed that the total number of design strategy segments was decreasing each week throughout the study (Fig. 9).

For additional information on design strategies at the micro-strategies level, the results were analysed and categorized within the three groups independently. In the solution analysis category, the highest number of critiques belongs to the group of rejecting a solution (Rs) as 32% of the total. Respectively, the frequently stated issues referred to the questioning of space properties (Qs) with 18%, the questioning representation (Qr) with 16% and questioning of object properties (Qo) with 15%. It was observed that there was no justification of solution (Js) or comparison (Co) issues.

In the proposing a solution category, it was found that the critics preferred to propose a single solution (Ps) for the design problem (96%) rather than proposing choices (Cs) for the solution (4%). None of the critiques had a reference to the previous solutions (Lp) of the design process.

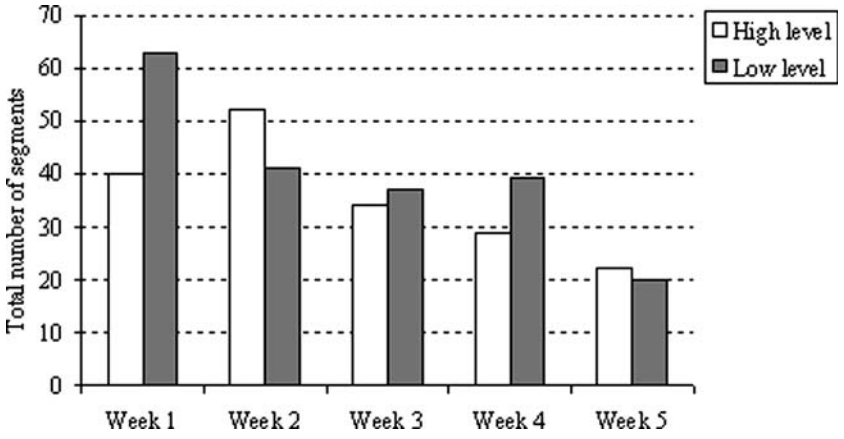

Fig. 10 Total number of design activity segments in each week

It was found that 63% of the total number of the explicit strategy category segments referred to the knowledge and requirements of the Design for Disabled course (Rdk) and 11% to the Design Studio course (Rsk). The reference to application knowledge (Rak) was 22% and the least number of references was found to be for a design strategy with 4%.

The analysis of the design activities indicated that the critiques were more related to the low-level design activities (53%) than the high-level design activities (47%). The number of segments referring to the high-level design activities decreased after the second week whereas a variable pattern was observed for the low-level design activities in the course of time (Fig. 10). However, the high and low level design activities did not differ significantly across 5 weeks ($\chi^2 = 6.26$, df $= 4$, $p = 0.181$).

In the low-level design activities, most of the references were to the accessories (36%) and furniture (36%) in the critiques of CDS process. The two issues, namely, layout and dimension were observed more than the other high-level design activities, as 48% and 26%, respectively.

Analysis of design diaries

In the analysis of design diaries, it was observed that the students were mostly dealing with the features of solution space (S-fe) (42%) and problem requirement (R-fe) (36%) in design process. The percentage distribution of the behavioural aspects of problem requirements (R-be) was less with 5% compared to the behavioural aspects of solution space (S-be) with 17%. In CDS, the emphasis given to the features and behaviour of the problem requirements and solution spaces varied in each week.

Discussion

On problem domain

The analysis of the redline files related to the problem domain indicated that there is a variation in the emphasis given to the different design issues. In the design abstraction

levels category, the most discussed issues were related to the details of the space and sub-spaces during the collaborative study. Gero and Mc Neill (1998) stated the results of their study related to the abstraction levels in each of the three design episodes. In the first and second episodes, the level of abstraction dimension involved reasoning mainly at the sub-system level. In the third one, it was distributed to both detail level and the sub-system level. These two studies have similar levels of abstraction that involves a detailed level of reasoning in design process.

In this study, the critiques of the collaborators referred more to the solution space than the problem space or representation. Maher and Tang (2003) also stated that the ''designer spent more time thinking about the solutions in the design process'' (p. 61). Furthermore in Demirkan's (2005) study, it is reported that the highest percentage of segments was related to the solution space. Therefore, the results of this study are consistent with the findings of the similar studies. Besides the small number of critiques regarding the representation supports that the collaborators did not have much difficulty in communicating design through the Internet. The DCM should also give support to critiques on the problem space. In a design process, it is the responsibility of designer to understand the end user problems, in their culture and their language and to find design solutions that meet their needs. Also, the designer should understand the needs of other parties whose lives will be affected by the designer's solution.

Both in this study and Demirkan's (2005) study, the behavioural aspects of the design and design elements were mostly discussed during the design communications to test and criticise the design solutions of the students. As Gero (1999) indicated, the particular behaviour and structure variables were produced in response to the various situations encountered by the designer. This means simply that the external representation does not match with the designer's expectation in many situations during the design process. As Schon (1987) defined it as the reflective practice, the interaction between the designer and the collaboration environment determines the course of designing. Therefore, this finding reports the situatedness character of the asynchronous CDS. However in Maher and Tang's (2003) study ''the numbers of structure type segments in both problem requirements and solution spaces exceed that in other types'' (p. 62).

On design strategies

In micro-strategies, generally unsatisfactory solutions were rejected and while proposing a solution only a single solution was stated instead of providing choices. The majority of the critiques were about the analysis of design in this study. Also, Demirkan (2005) stated that the greatest number of the critiques were about the analysis of design. But she added that the explicit strategies were in the second place, whereas in this study the least number of critiques were related to the explicit strategies. However, Gero and Mc Neill (1998) found that the designer was more involved in the proposal of a solution in the first and second design episodes. But in the third episode, while the designer was cycling between the proposal of a solution and analysis, spent almost equal time in both.

In this study, the total number of segments that were related to the low-level activities was high, whereas in Demirkan's (2005) study it was the high-level ones. In this study, the layout, accessories and furniture were discussed in almost all of the design critiques. Many of the references and critiques were related to the Design for Disabled course where the new issues were introduced in the design project.

Also, the correlations among the design issues and the performance scores of the students were tested. The highest correlation was found between the number of segments and the performance scores of the students (Coefficient correlation = 0.709), indicating that the grades of the students were getting higher as the number of segments in redlines increased. This showed that the number of critiques do not determine the success level of proposed design solutions. However, the content of the critiques is correlated to the success level of design solutions.

On design diaries

Analysis of the design diaries showed that the students gave more emphasis to the features of the solution space when revising their projects. This was a similar approach to the face-to-face communication that occurs in the traditional design studio. The students with the highest grades had more segments related to the features of the solution space. There was no finding about the students with the lowest grades, since most did not submit the design diaries as required each week.

Finally, since all of the students and the instructors had experience with the computers, they did not have any difficulty during the collaboration sessions with the design presentations in CDS. The most commonly mentioned problem was the amount of time spent to download or upload the design files. This was caused mainly by the breakdowns of the Internet connections, which was a general problem all over the country at that specific time. However, the students stated that they found the DCM satisfactory for design collaboration because it was easy to learn and use (Sagun and Demirkan 2005). Kvan et al. (1999) found that the participants in a chat line communication explore more ideas than the audio–video condition in the computer mediated environments. Similar communication tools should be adapted to the web-based collaborative environments to enhance the design education.

Conclusion

This study was an attempt to model and analyse a collaborative study environment where information among the collaborators was implemented through the given critiques via Internet. Another goal of the study was to observe the design process by decomposing the given critiques into typical segments depending on the intentions of the designer. The analysis of the segmentation of design domain and strategies enabled an insight on design process through the given critiques. The integration of quantitative and qualitative analysis methods provided a broader perspective for the understanding of the design process. Analysis of quantitative data informed us about the distribution of the number of critiques and segments across 5 weeks. Also, the level of collaboration was determined and no significant relationship was found between the instructors and the given number of critiques.

The study was based on the two characteristics of the design process. The design process has a reflective nature in the sense that the collaborators develop their design by reflecting their new ideas and solutions in each step as a result of the critiques. Additionally, the design process is shaped according to the nature of the given critiques. The designer was required to redesign the project according to a new situation stated in the given critiques. These two characteristics of design were explored and investigated in the Internet environment thereby providing flexibility on time and space for the design process.

Also, it was observed that this framework provided a medium for the integration of knowledge obtained in two design courses. It was observed that the characteristics of transferred knowledge through the critiques determine the success level of proposed design solutions.

Finally, the study highlights the point of view of students and instructors in an online collaborative design environment. The research studies on the development of collaborative design software and environments need to be supported by the experiences of users. The findings of this study and similar research approaches help the improvement of collaborative design studios in design education.

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Appendix

Appendix A Examples for redline segments in problem domain

Segment	**P/S/R**
The internet area and the TV area are missing!	P, problem
Layout of the area is sparse compared to the rest of the lounge	S, solution
What is this line?	R, representation
Segment	**DA**
This is an uncomfortable situation for a CIP lounge where you are trying to create a prestigious environment.	0, whole space
You can load some functions to reception like a little cloakroom in it. It will help u to shape, the reception.	1, sub-spaces
The circulation to/from the toilets' the circulation to/from the kitchenette and the service circulation to/from the service entrance are congested at this area	2, interactions among sub-spaces
Does this grab bar become an obstacle to sit on the seat?	3, interactions among objects
The curved partition panel placed at the entrance does not solve the problem!	4, details of the space
Be careful with the sharp corners! You should round the corners of the coffee table.	5, details of the objects
It is hard to pass through for a wheel-chair user.	Rd, requirements of ''Design for Disabled''
The CIP lounge should introduce different layout groups for different numbers of patrons.	Rs, requirements of ''Design Studio''
What is this line?	U, undefined
Segment	**F/B/S**
Also symmetrical arrangement of the drink counters is unnecessary and difficult to maintain the service.	F, function
The obstacles on the way to the shower tub may create some accessibility problems.	B, behaviour
Did you think of any sound insulation precautions?	S, structure

Appendix B Examples for redline segments in design strategies

Micro-strategies

Segment	Analyse a solution
It is very important to give alternatives for both the left-handed and right-handed people. Thank you*	Js, Justify a design decision
The coffee table in the middle is huge to be reached.	Rs, Reject a design decision
If you leave so much space in a cubicle like this for the healthy people than they may feel themselves as lost.	Cu, Clarify a problem in future use
There are no grab bars around the WC.	Wm, Warning for missing issues
The last drawing was better for nursing area*	Co, Comparison
You still did not change the design of grab bars.	Rp, Refer back to a previous solution
Did you think of any sound insulation precautions?	Qs, Question space properties
Does this grab bar become an obstacle to access seat and sitting down?	Qo, Question object properties
Is there a wall there?	Qr, Question representation
Where will these people store their clothes?	Qc, Question design concept

Segment	Propose a solution
You can assign some functions to the reception hall like a little cloakroom in it. It will help you to shape the reception.	Ps, Propose a solution
To locate either the door or the WC/lavatory area on the other side will create an easy access and manoeuvring area.	Cs, Choices for solution
The last drawing was, better for nursing area*	Lp, Refer to previous solution

Segment	Explicit strategies
Sofa for three people cannot be used efficiently in a lounge like this. No one will like to seat shoulder by shoulder.	Rak, Refer to an application knowledge
You must leave 30 cm free space on the latch side of the doors for the feet of wheelchair user. Otherwise the doors cannot be opened.	Rdk, Refer to the DD Knowledge and requirements
The Internet area and the TV area are missing! (If they exist somewhere on this plan, they are not as defined space-wise, as required by the project)	Rsk, Refer to the DS knowledge and requirements
How do you provide food service to the counter from the kitchenette without interrupting the public circulation?	Rds, Refer to the design strategy

Design activities

Segment	High level
The CIP lounge should introduce different layout groups for different numbers of patrons.	LY, Layout
The circulation to/from the toilets‘ the circulation to/from the kitchenette and the service circulation to/from the service entrance are congested at this area.	CR, Circulation
If you leave so much space in a cubicle like this for the healthy people, they may feel themselves as lost.	DM, Dimension
Symmetrical arrangement of the drink counters is unnecessary and difficult to maintain the service.	SH, Shape

Appendix B continued

This type of a kitchen wall may create some utility system problems and also it cannot be perceived easily by the users and the customers. Do you really have to design that wall in that curvilinear shape?	CS, Construction system
Does this grab bar become an obstacle to access the seat and sit down?	OA, Obstacles/Accessibility
What is this line?	U, Undefined decisions
Segment	**Low level**
No night lamps?	LT, Light
What is the material in between these two people who are expected to make private telephone conversations?	MT, Material
Sitting shoulder by shoulder is not a good solution. A sofa for two and two armchairs will be better.	FR, Furniture
For my opinion‘ people do not have time to read a book but they may read a magazine or newspaper so may be labelling there as ’’shelves for magazines & newspaper’’ is better.	SG- Signs
This type of a grab bar can be very dangerous. You should have left only 4 cm space between the wall and the grab bar. Otherwise the user may break his/her arm.	AC-Accessories

* Example from the pilot study

Appendix C Examples for design diary segments

Segment	**Requirements and solution**
I put the food counter in front of the kitchen door to prevent the traffic between kitchen and food counter.	R, fe
According to the critics, I understood that the traffic in between WC and kitchen would create chaos.	R, be
I used sliding doors for the entrance of the shower rooms.	S, fe
Also I put the Internet and telephone services in the same area so the reception area became bigger.	S, be

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