PROBLEM BASED LEARNING IN ARCHITECTURAL EDUCATION

Alan Bridges
Department of Architecture, University of Strathclyde, Glasgow, UK

ABSTRACT: There is limited published research and discussion on pedagogical approaches in architectural education. Problem (or Project) Based Learning is used successfully in other professional disciplines, and, consequently, there have been attempts to utilise the same pedagogical approach in architectural education. This paper critically reviews PBL implementations at the Faculty of Architecture, Technical University of Delft (TUDelft), Netherlands and the Department of Architecture, University of Newcastle, New South Wales, Australia and draws general conclusions about the implementation of PBL in architecture and particular recommendations with respect to the teaching of architectural computing.

KEYWORDS: PBL; architectural education; computing.

1 PROBLEM / PROJECT BASED LEARNING IN ARCHITECTURAL EDUCATION

There is only a limited literature available on the relevancy and effectiveness of PBL implementation in architectural education. PBL in architectural courses is usually confined to the studio and does not affect or interact with the teaching of other subjects in the curriculum (Maitland, 1997). The challenge becomes more severe when the goal is to simulate true-to-life design tasks across the whole curriculum (Westrik and de Graaff, 1994), but such work as is reported is usually limited to presenting the curriculum structure and the learning theory of an architectural version of the PBL pedagogical approach. In general terms, Boud and Felletti (1997) consider that discussions of PBL are mostly focused upon the aspects that are "more descriptive of process" rather than "analytical of either process or outcome." The exact questions of PBL relevancy, and how the PBL implementation is carried out in the most distinctive features of architectural education, its contents and its conventional teaching methods, have not been elaborated.

A number of authors have reported experiences of using PBL in the teaching of architectural computing (Goldman and Zdepski, 1987; Kalisperis, 1996; Marx, 1998; Johnson, 2000; Rügemer and Russel, 2000; Wyeld et al, 2001, Silva, 2001, Delgado, 2005). However, most of them deal with specific teaching modules, which are applied within the boundaries of the design studio itself or try to integrate computing into an existing curriculum (Juroszek, 1999) rather than causing actual changes to its structure.

2 PBL AT THE TECHNICAL UNIVERSITY DELFT, NETHERLANDS

Before the introduction of PBL, the curriculum essentially consisted of a series of design projects complemented by technical courses and skill development exercises. Students could choose from over 1000 different courses and projects. There were large differences in the quality of projects, integration with other parts of the curriculum often failed and the programmes were almost impossible to manage. The problem was made worse by the scale of the faculty: having approximately 2,400 students and over 450 staff members either permanent or part-time, the Faculty of Architecture was one of the largest faculties in the university. This, in itself, made managing the educational program and integration of the curriculum almost impossible (de Graaff and Bouhuijs, 1993a; de Graaff, 2001). Furthermore, the cost of managing such a large faculty was also considered too high (de Graaff and Bouhuijs, 1993a).

All of these problems were recognised by the Dutch Ministry of Education who considered that the way architecture was taught in the faculty was not sufficiently based on the comprehensive technological and scientific foundations expected in a technical university (Verkenningscommissie Bouwkunde, 1988). Given that there were also some 30 art academy Schools of Architecture in the Netherlands and that the TUDelft training was more expensive, these two factors led to the ultimatum received from the ministry: the Faculty would have to be closed down unless major improvements were made.

A decision to undertake a large scale educational restructuring was initiated by the Faculty Board in 1989 (Woord and de Graaff, 1993). With support from educational advisors from the Limburg State University of the Netherlands, a committee - the Program Committee Building

Sciences (PKB) - was established to introduce PBL as a way of improving the performance of the Faculty of Architecture (de Graaff and Cowdroy, 1997). Although the staff did not agree unanimously, and there was a time constraint on the preparation of the PBL curriculum, the implementation of PBL was executed six months after the establishment of the committee (de Graaff and Cowdroy, 1997).

2.1 *The PBL curriculum structure*

The proposed PBL curriculum structure for the Faculty of Architecture consisted of four years study duration divided into two cycles. The first cycle, for years 1 and 2 was structured in thematic blocks, each containing a broad introduction to architectural principles and technologies (Bosch and Gijselaers, 1993). It was intended to provide students with the basic insight, knowledge and skills required by the architectural profession (Woord and de Graaff, 1993). The second cycle, for years 3 and 4, was multidisciplinary in character (Bosch and Gijselaers, 1993). Here, each student had the choice to specialise in one of the five majors traditionally offered by the Faculty: architecture, building management, building technology, housing or urban design (Woord and de Graaff, 1993).

The first cycle of the PBL curriculum was divided into 12 study periods, each approximately 6 weeks long, and called the "thematic blocks". These thematic blocks were arranged in a fixed sequence (de Graaff and Bouhuijs, 1993b; de Graaff and Cowdroy, 1997). Each block focused on a particular theme, enabling students to work on a series of "cases" related to the designated theme, which was derived from questions or problems areas of building sciences practice (de Graaff and Kolmos, 2003). The themes designed for the 12 blocks were the house; the building process; the city; the building; the wet cell; the area; the building program; form and function; the technical installation; the environment; renovation and second use; and materialisation (de Graaff and Bouhuijs, 1993a).

The thematic blocks were intended to replace the traditional teaching of lectures with PBL small group work (although lectures were given in addition where students did not have enough prior knowledge to work with more complex themes unaided) and to replace the traditional design project with a "limited" design exercise. Support was provided from teams of teachers, who acted as facilitators during analysis of problem in PBL small group discussions (de Graaff and Cowdroy, 1997) and as supervisors in the design exercises session taking place in "studio like setting" (Frijns and de Graaff, 1993). Additionally, students were also provided with various forms of learning resources, such as literature and videos.

In the second cycle, the sequential order of blocks was abandoned and replaced by the provision of compulsory and elective subjects organised in the form of modules. In the third year of study, students would have the options to choose modules that were related to their specialised majors. In the early stage of the students' third year study, they were not required to commit themselves to any one of the five majors offered. However, prior to the completion of their third year study, they would have to make a definitive choice, either to majoring in architecture, building management, building technology, housing or urban design. Consequently, the fourth year was dedicated to work on students' final graduation projects (Woord and de Graaff, 1993).

2.2 *Organisational structure*

Radical changes were made to the organisational structure in order to establish centralised control over the new curriculum structure, and to ensure successful implementation of the PBL curriculum (Bosch and Gijselaers, 1993; Woord and de Graaff, 1993). The proposed organisation structure had two levels of management. At the macro level, committees were responsible for controlling and monitoring the PBL implementation, whilst, at the micro level, academic staff were responsible for carrying out the implementation process. At the macro level, the Faculty Board (FB) had the ultimate authority, with input from the Study Advice Committee (SRK) and The Faculty Council (FR) (Woord and de Graaff, 1993). The FB installed the Implementation Committee for Building Education (ICOB) with the responsibility for the development of the new PBL curriculum, and the coordination of the whole implementation process. ICOB was chaired by the Dean of the Faculty and coordinated the micro level of the organisation structure. Ironically, members of ICOB were selected on the basis of "personal merit," rather than as representatives of various existing departments within the faculty (de Graaff and Bouhuijs, 1993b; de Graaff and Cowdroy, 1997). Therefore, the de facto organisational structure was not reflected in ICOB.

ICOB played the main role of connecting the macro and micro levels. Some members of ICOB were also members of year planning groups (JPG). The JPGs main function was to coordinate the educational programme and the evaluation of the course year concerned (Woord and de Graaff, 1993). JPG consisted of twenty three (23) members (de Graaff and Cowdroy, 1997), including the year coordinators who chaired the meeting within block groups, the block coordinators invited from the existing different departments, the skill acquisition coordinator, and one or two students representatives (Woord and de Graaff, 1993). Hierarchically below JPG, the block coordinators chaired their respective curriculum groups, or block groups. Each of the block group had further subdivisions, six thematic blocks for the first and second years and five disciplines for the major graduation years.

The proposed new organisation structure that accompanied the introduction of PBL in the Faculty of Architecture was far more complex than the traditional organisation structure that had discipline-oriented departments. This complexity proved to be too complicated for the general academic staff to fully participate, especially as the traditional structure was not entirely abandoned, but still functioned to organise the modules offered in the matrix organisation of the third year, and the major graduation projects of the forth year (Bosch and Gijselaers, 1993). The PBL's new curriculum structure, that consisted of thematic blocks and a matrix organisation of "differentiations", was actually erected as a "shadow" to the traditional structure (de Graaff and Cowdroy, 1997). As such, the two didactic systems ran concurrently for several years. The traditional organisation structure also needed to be maintained during the early part of PBL im-

plementation as the old curriculum was still in operation to accommodate the remaining students who started their architectural education under that system.

2.3 *Didactic cultural changes*

The Faculty Board (FB) was aware that a staff development program would be needed in order to raise the commitment of staff and students, and to stimulate wide participation in the PBL implementation. As such, the FB outlined a staff development program by means of "teacher training" sessions. These were planned to introduce academic staff to the educational strategies of the new curriculum (de Graaff and Bouhuijs, 1993b). The training focused on both development of the new PBL educational techniques, and the acquisition of new attitudes towards the learning concept (Woord and de Graaff, 1993).

The Department of Educational Research and Development of the University of Limburg, Maastricht, the Netherlands, was commissioned to provide the needed teacher training in the Faculty of Architecture, TUDelft (de Graaff and Bouhuijs, 1993b). Academic staff in the Faculty of Architecture received their first training in PBL from the Maastricht consultants in January 1990.

Moreover, to make the staff development program more effective, some of the academic staff were given the responsibility to prepare blockbooks that served as guides for both academic staff and students in their endeavour to adapt to the new learning philosophy. Constructing their own blockbooks was believed to inspire a deeper understanding of the PBL implementation concept and process. Indeed, the prepared blockbooks had to be approved in advance by the programme committee prior to the implementation to confirm the academic staff's understanding of the philosophy of PBL (Woord and de Graaff, 1993; de Graaff and Bouhuijs, 1993b).

There was no specific programme designed for students' development prior to the implementation of PBL in the Faculty. It was expected that staff who had undergone the training sessions were expected to transfer the PBL philosophical concept and its learning techniques to students during the implementation process.

2.4 *Assessment methods*

Frijns and de Graaff (1993) noted that the choice of assessment methods should be congruent with the educational and instructional principles of the new PBL curriculum, as different types of assessment evoke different study behaviour among students. In this case, the Faculty took the decision to assess students' ability in three competency domains: factual knowledge, practical and technical skills, and design proficiency. Students' factual knowledge was tested by mean of examinations, which came in the forms of true or false items, multiple choice questions and open-ended questions. The examination took place at the end of each block period, with minimum passing grade of 5.5 on a ten-point scale. The lack of expertise in the construction of true or false questions raised structural problems with the quality of questions presented to students, and worse, the true or false items were considered to focus too much on factual knowledge in a way that acted against the integrative philosophy of a PBL pedagogical approach. In addition, the open-ended question was seen as lacking reliability, and was too time-consuming to mark.

In a different way, students' practical and technical skills were measured by using assignments, oral presentations, written essays, and work samples. This assessment method was carried out, based on either students' individual works, or their group work. On the other hand, design proficiency was assessed in a very similar way to the traditional architectural design education, where students' works were graded using criteria outlined by "juries". This assessment method still raised points of serious concerns because of its unlimited breadth of "subjectivity of rating,' that resulted in a very time-consuming assessment process (Frijns and de Graaff, 1993).

3 PBL AT THE DEPARTMENT OF ARCHITECTURE, UNIVERSITY OF NEWCASTLE, NEW SOUTH WALES, AUSTRALIA

The decision to adopt PBL in the Faculty of Architecture, University of Newcastle, New South Wales, Australia was also influenced by the fact that the Faculty faced several problems regarding its existence in the university. As the smallest faculty in the university, and one of the smallest faculties in Australia (de Graaff and Cowdroy, 1997), the Faculty of Architecture struggled to keep up with 14 larger professionally accredited architecture schools in Australia which provided better facilities to students. In competition with larger architecture schools, the faculty experienced a period of "instability and doubt" over its future (Maitland and Cowdroy, 2001), due to the problems of maintaining distinct disciplines which were found in the larger faculties, keeping academic staff commitment to the faculty development, and keeping design as the central and most important aspect of its architecture course (de Graaff and Cowdroy, 1997).

The faculty had a small academic staff: only ten full time teaching staff, three staff on fractional appointments, and 20 "sessional" teachers, including several postgraduate tutors (Maitland and Cowdroy, 2001). With this small scale of faculty, the struggle to maintain the same disciplines as in the two tier degree structure of architecture course duplicated from the University of New South Wales caused the academic staff to have a substantial teaching load that consequently led to staff dissatisfaction (de Graaff and Cowdroy, 1997).

With support from architects' profession in Newcastle, the Faculty of Architecture decided to review its architecture curriculum. In order to initiate changes, whilst enhancing Architecture's distinctive profile in the faculty a process of "critical self-evaluation" was begun. Through numerous debates, workshops and seminars, the faculty came to focus on the key problems of relevancy and integration in the architectural curriculum (Maitland and Cowdroy, 2001). A course review undertaken in 1984 also concluded that the primary objectives of an architecture curriculum should include the relevance of content, and integration of areas of knowledge around the central focus of design (Ostwald and Chen, 1994). Any means of renewal

should consider keeping the curriculum relevant to the current changes and innovations in architectural profession regionally and worldwide. In addition, renewal should also be able to overcome the problem of separation between different strands of the architectural curriculum (Maitland and Cowdroy, 2001).

It was then discovered that the Medical School in the same university had been using a PBL pedagogical approach since 1976 (de Graaff and Cowdroy, 1997) to address similar problems of "relevance and curriculum fragmentation" (Maitland and Cowdroy, 2001). The faculty then took advantage of the "smallness and provincial location" of the faculty to get a unanimous decision to experiment with a similar approach using PBL. Since there was still some trepidation, the undertaking of PBL approach would only be done on basis of a trial, in case it did not work, the new programme would be abandoned (de Graaff and Cowdroy, 1997).

3.1 *PBL curriculum implementation*

The Faculty of Architecture developed a PBL architecture curriculum from a variation of the medical model with support from curriculum development staff of the Medical Faculty in the same university (de Graaff and Cowdroy, 1997). However, the faculty realised that the natures of medical and architectural disciplines were different, the former was concerned with "discovery and diagnosis" whilst the latter was about "invention and finding responses to problems for which there was no one correct solution" (Maitland and Cowdroy, 2001). As such, direct adoption of the medical PBL approach would not be appropriate to architecture. Instead, the faculty referred to Schön's (1985) ideas of enhancing the design studio as a powerful model for an architectural form of dynamic problem solving. The faculty resolved to strengthen the design studio that had declined in the faculty, by using PBL to generate "an integrated problem solving environment" in the studio (Maitland and Cowdroy, 2001). One proclaimed strength of this resolution of coupling Schön's ideas and PBL approach was the relevance of the students' learning to real architectural practice (Ostwald and Chen, 1994).

The Faculty started to implement the new PBL approach in March 1985 for the first year students (Maitland and Cowdroy, 2001). It was the Faculty's intention to introduce PBL progressively to the curriculum of years 2, 3, 4 and 5 in succeeding years with the same cohort of students (de Graaff and Cowdroy, 1997). However, the entire 5-year programme was converted to the PBL approach in 1987, only two years after its introduction, due to the demands of students in later stages of the course that they should also be included in the new approach (Maitland and Cowdroy, 2001). The decision to accelerate the conversion process was also due to the difficulty faced by the faculty in running two different educational approaches in parallel (de Graaff and Cowdroy, 1997).

3.2 *Curriculum structure*

The curriculum structure in the Faculty was organised in the form of a two-tier degree structure. Three years study was required for students to gain the Bachelor of Science, with an additional two years of study to receive their Bachelor of Architecture that entitled them to be graduate architects. However, the new PBL curriculum structure was implemented mainly in the first, second and third years of the architectural programme. In the fourth and fifth years of study, students were presented with a "more comprehensively integrated approach" that was called Integrated Learning (IL) or Integrated Problem Based Learning (IPBL) (de Graaff and Cowdroy, 1997), that was in itself an integration of ideas of the studio-based learning model and the Problem Based Learning model. Unlike the PBL implementation in the Faculty of Architecture, TUDelft, and in most medical schools that focus on short duration of problem cycles in block themes, the implementation of PBL in the Faculty of Architecture, University of Newcastle, maintained the centrality of design problems in its semester-like curriculum structure. A semester lasted for several months, and each year of study was divided into two semesters. This semester structure enabled the lengthy process of integration and reconciliation to take place successfully and to cover most aspects of architectural content adequately, ranging from the real identification of needs, the conceptual design phase, to the detailed constructional drawings of the proposed solutions (Maitland, 1997). Nonetheless, the two semesters of each year were still linked to a particular theme, based on building typologies, so that students would be exposed to a full range of types, each with its particular social, economic and cultural context (Maitland, 1997).

In this IPBL approach, the problem of integration was tackled by eliminating boundaries between disciplines and subjects, so that seven combined study areas emerged. The combined study areas were professional skills, user studies, site studies, cultural studies, design studies, technical studies, and implementation studies. The emergent study areas focused on developing particular sets of knowledge, skills, specialisations, and expertise to reflect the modus operandi of architects in current practice, as precisely identified by the Australian Architects' Registration Boards and the Professional Institute (Maitland, 1997). Here, the relevance of IPBL curriculum and architectural learning methods were demonstrated by presenting students with real design problem and real clients, selected from particular model firms of architects (de Graaff and Cowdroy, 1997).

By eliminating independent lecture courses, the intersected arrangement of a two tier degree structure and seven integrated study areas formed a matrix organisation, in which the "individual study areas were introduced and developed through their successive application of problem exercises". The essence of the integrated approach was that the knowledge and skills developed in each study area must be capable of being applied in the context of design problems presented. Presented in the form of project briefs, the design problems set for each theme or semester were meant to drive the integration of various study areas and the content of the curriculum around the central activity of design.

The implementation of a PBL pedagogical approach in the Faculty of Architecture, University of Newcastle, required only a slight change in the faculty organisational structure. There was no need to make significant changes for the reason that the faculty did not encounter any diffi-

culty in establishing control in the management. The new organisational structure reflected the implementation of PBL by providing design studios with additional support from coordinators and consultants of identified study areas. This additional support meant to replace the lectures classes provided in the traditional curriculum structures.

3.3 *Assessment methods*

The implementation of PBL in the Faculty of Architecture at University of Newcastle revitalized changes in the assessment method as well, to bring about a "somewhat complex" assessment system (Banerjee, 1994). Here, students were assessed in the form of a "continuous grading of work through the year, with mid and end of year reviews, and a final compilation of assessment into a single graded year result" (Maitland, 1997b). This continuous form of assessment process served not only as evaluation and feedback of students' performance, but also as an integral part of the whole learning process (Cowdroy and Maitland, 1994). Thus, the architecture PBL curriculum had "twin priorities" in its assessment process; students' ability in design integration, and their knowledge and skill development in the seven study areas (Maitland, 1997b). Students' performance in design integration was allocated 50% of the overall assessment, and the remaining 50% was allocated for their knowledge and skill in individual study areas. As both areas had equal importance, students were required to achieve an adequate standard in each of the required domains (Maitland and Cowdroy, 2001).

Assessment of students' ability in design integration was within the province of group tutors and year managers who played the role of design juries. With the company of invited guests, a panel of juries periodically reviewed and critiqued students' work, most commonly at intermediate and the end stages of a problem phase (Maitland, 1997). The assessment of students' knowledge and skill in the 7 individual study areas was done by study area consultants in two ways. Firstly, consultants assessed students through the main design submissions and its phase works, based on criteria and objectives set by them and given to students at the start of the problems (Maitland, 1997). Secondly, students' knowledge and skill were assessed through a separate design assignment, submission of report, laboratory work, tutorials, and examination (Banerjee, 1994; Maitland, 1997).

4 GENERAL CONCLUSIONS

The decision to introduce PBL should be discussed amongst not only the decision makers, but also the architectural academic staff who would be involved in the implementation process.

The design of an architectural version of PBL should be done with advice and references not exclusively from the general educational specialists who are experts in PBL pedagogical approach, but also from architectural teaching staff.

In terms of curriculum design, the nature and types of problems to be used as the triggers for learning in architectural PBL pedagogical approach should be thoroughly researched and developed, for relevancy, before the commencement of the PBL implementation.

Issues of relevancy should also be confronted in terms of what suitable PBL mechanisms may be included in the proposed architectural PBL approach. Relevancy of PBL mechanism, such as its learning process and techniques, to architectural studies and disciplines must be analysed at the planning stages to ensure its suitability to architectural education. For example, PBL group discussion alone is not enough to generate integration in architectural studies, but the experiential "learning by doing" feature of the conventional methods of architectural teaching should also be incorporated to ensure that the provision of design skills development is available in the proposed system.

In terms of curriculum structure, the design studio should be used as the arena for integrating architectural knowledge. Having separated venues and time allocations for PBL group discussion and design studio, as had been practiced in the Faculty of Architecture at TUDelft, does not contribute to the comprehensive integration of knowledge. Since architectural education requires both the accumulation of architectural knowledge and the development of various skills among students, too much emphasis on group discussion may jeopardize the development of various professional skills required for architectural students.

A degree of flexibility should be allowed for. For example, a strict ban on the use of lectures as one of the learning techniques should be waived so that any architectural knowledge that could not be disseminated via group discussion, such as history, could also be incorporated in PBL. Flexibility in the assessment methods should also be provided to give weight to the conventional architectural method of assessing design product as part of a PBL mechanism.

In terms of the issues of managing change, a proper monitoring system of the PBL implementation process should be designed and carried out by an elected committee.

The design of an architectural version of PBL should include the provision of staff induction, training, and development to promote understanding, acceptance and commitment among the academic staff towards the implementation. Academic staff should master methods of delivering knowledge in PBL before the implementation even starts, so that the proper role of facilitators can be practiced in the learning process.

5 SPECIFIC POINTS OF RELEVANCE TO THE TEACHING OF ARCHITECTURAL COMPUTING

The problem should be sufficiently complex to not only engage the students' interest but also bear some relationship to real world circumstances. Simply finding out how to operate a particular piece of software may be seen as a parallel to the bathroom mirror example. Suitable projects should relate to design studio work and not be seen as separate activities away from the main focus. One example might be the modeling and representation of precedents related to the current studio project.

The task should be open to multiple interpretations. In architectural computing this might encompass the selection of alternative software packages or forms of representation.

The assignment should be of sufficient duration to allow students to meaningfully engage with the problem. As indicated previously six weeks appears to be an optimum duration.

Teamwork and sharing of information leads to an enhanced learning experience.

Reflection on learning outcomes and skills gained is of particular importance. Students acquire important "generic skills" in these classes and it is worth reflecting on these skills and documenting them in "Personal Development Portfolios".

The project should allow for the development of a range of skills. Examples might include the mixing of scanned and manipulated traditional media with computer generated media or photo-montaging CAD images onto scanned photographs. Presentations may use hardcopy media or projected images.

CAD modeling and imaging may be taught alongside traditional manual drawing and modeling.

The selection of suitable precedents is crucial. One of the key considerations is the availability of sufficiently detailed and accurate source material to work with.

The project is more meaningful if the participants have been involved in the collaborative definition of the problem formulation.

ACKNOWLEDGEMENTS

The structured interviews for the TU Delft evaluation were carried out by Fadzidah Abdullah as part of her PhD research (Abdullah, 2006).

REFERENCES

Abdullah, F. (2006) *An Evaluation of Problem Based Learning in Architectural Education*, Unpublished PhD thesis, University of Strathclyde, Glasgow, U.K.

Banerjee, H.K. (1994). Handling of A Specialist Subject in An Integrated Problem Based Learning Programme, In S.E. Chen, Cowdroy, R., Kinglands, A., & Ostwald, M. J. (Eds.), *Reflections on Problem-based Learning (pp.219-235).* Sydney: Australian Problem Based Learning Network.

Bosch, H., and Gijselaers, W.H. (1993). The Introduction of Problem-based Learning in the Faculty of Policy and Administrative Sciences: a Management Approach. In E. De Graaff & P.A.J. Bouhuijs (Eds.), *Implementation of Problem Based Learning In Higher Education* (pp. 31-37). Amsterdam: Thesis Publishers.

Boud, D. and Feletti, G. (1997) *The Challenge of Problem-Based Learning*, Kogan Page Ltd, London, UK.

Delgado, F. (2005) Designing a Problem-Based Learning Course for Mathematics in Architecture, *Nexus Network Journal,* vol. 7 no. 1 (Spring 2005)

Frijns, P., and De Graaff, E. (1993). The Assessment of Study Results in Problem Based Curriculum. In De Graaff, E. & Bouhuijs, P.A.J. (Eds.), *Implementation of Problem Based Learning in Higher Education* (pp.57-61). Amsterdam: Thesis Publishers.

Goldman, G. and Zdepski, S. (1987) Form, Color and Movement, Integrating Computers into the Architectural Curriculum *in ACADIA Conference Proceedings*, Raleigh, North Carolina, USA, pp. 39-50.

de Graaff, E. (2001). How to Enable a Self Regulating Learning Process: New Teacher Roles in Engineering Education*. ALE 2001 Workshop*. Caracas, Venezuela: Active learning in engineering Education.

de Graaff, E. and Bouhuijs, P.A.J. (1993a). The Introduction of Problem Based Curriculum at the Faculty of Building Sciences, In E.De Graaff, & Bouhuijs, P.A.J. (eds.), *Implementation of Problem Based Learning in Higher Education* (pp.17-24). Amsterdam: Thesis Publishers.

de Graaff, E. and Bouhuijs, P.A.J. (1993b). The Implementation of Problem Based Learning at the Faculty of Building Sciences: Management of Educational Change. In E. De Graaff, & Bouhuijs, P.A.J. (Eds.), *Implementation of Problem Based Learning in Higher Education (*pp.25-29). Amsterdam: Thesis Publishers.

de Graaff, E. and Cowdroy R. (1997) Theory and Practice of Educational Innovation; Introduction of Problem-Based Learning in Architecture, *International Journal of Engineering Education*. Vol 13 no 3 pp 166-174.

de Graaff, E. and Kolmos, A. (2003). Characteristic of Problem Based Learning. *International Journal of Engineering Education*, 19 (5), 657-662.

Johnson, B. R. (2000) Sustaining Studio Culture: How well do Internet Tools Meet the Needs of Virtual Design Studios?, in Donath, D. (editor) *Promise and Reality*, eCAADe proceedings, Bauhaus-Universität, Weimar.

Juroszek, S. (1999) Access, Instruction, Application: Towards a Universal Lab, in Brown, A., Knight, M. and Berridge, P. (editors) *Architectural Computing: from Turing to 2000*, University of Liverpool, UK.

Kalisperis, L. (1996) CAD in Education: Penn State, in *ACADIA Quarterly*, volume 15, number 3 (summer): 22-25.

Maitland, B. (1997) Problem-based Learning for Architecture and Construction Management, in Boud, D. and Feletti, G.: 1997, *The Challenge of Problem-Based Learning*, Kogan Page Ltd, London, UK.

Maitland, B. and Cowdroy, R. (2001). Redesigning PBL: Resolving the Integration Problem, In P. Schwartz, & et. al. (Eds.), *Problem-based learning: Case studies, Experience and Practic*e (pp.90-97). London: Kogan Page Limited.

Marx, J. (1998) A Proposal for Alternative Methods for Teaching Digital Design, in van Wyk, S. and Seebohm, T. (Editors), *Digital Design Studios: Do Computers Make a Difference?,* 59-73, ACADIA'98 Proceedings, Québec City, Canada.

Ostwald, M.J. and Chen, S.E. (1994). Marginalisation of Theoretical Issues In A Professional PBL Course : A Structural or Attitudinal Problem? In Chen, S.E., & et al. (Eds.), *Reflections on Problem-based Learning (pp.87-103).* Sydney: Australian Problem Based Learning Network.

Rügemer, J. and Russel, P. (2000) Promise and Reality: The impact of the Virtual Design Studio on the design and learning process in architectural education, in Donath, D. (editor) *Promise and Reality*, eCAADe proceedings, Bauhaus-Universität, Weimar.

Schön, D.A. (1985). *The Design Studio: An Exploration of Its Tradition and Potential*. London: RIBA Publication Limited.

Silva, N. F. (2001) The Structure of a CAAD Curriculum and the Nature of Design Process in Architectural Information Management, *Proceedings of eCAADe 2001*, Helsinki, pp 352-357

Verkenningscommissie Bouwkunde (1988) Eindrapportage (Final Report)

Westrik, J. and de Graaff, E. (1994) Development and management of the new PBL-based curriculum in Architecture in: S.E. Chen, R.M. Cowdroy, A.J. Kingsland and M.J. Ostwald (eds*.) Reflections on Problem-based Learning.* Sydney: Australian Problem Based Learning Network.

Woord, J.V.D. & De Graaff, E. (1993). Changing Horses Mid-Course: The Implementation of a Problem Based curriculum At the Department of Building Sciences of the Technical University Delft, Holland. In P.A.J. Bouhuijs, Schmidt, H.J., & & Van Berkel, H.J.M. (Eds.), *Problem Based Learning as an Educational Strategy.* Maastricht: Network publications.

Wyeld, T., Woodbury, R. and Shannon, S.: 2001, Leitmotif Cases for Design Learning, in Gero, J., Chase, S. and Rosenman, M. (Editors), *CAADRIA 2001*, University of Sydney, Faculty of Architecture, Australia.