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Spatial support of knowledge production in higher education

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ABSTRACT

This paper explores the impact of the physical and social dimensions of the work environment on satisfaction and perceived productivity of knowledge workers in Dutch universities of applied sciences. The approach took the form of a literature review, multiple case study of six research centres using interviews and logbook analysis, and web-based survey (N = 188). Optimally facilitating knowledge production requires both space for concentration (to support internalisation of knowledge) and space for interaction (to support externalisation of knowledge). None of the work environments involved in the study adequately supported all the phases of knowledge development adequately. Cellular offices with personal desks are preferred for solo work and, whereas new workplace designs with a focus on the office as a meeting place support interaction and collaboration. Spatial layout and interaction have a stronger impact than comfort and absence of distraction. The spatial layout should support both in-depth concentration and communication, fit the internalisation/externalisation ratio of activities, and accommodate the proximity essential for collaborative knowledge development. Being able to choose is the key to success. In terms of research limitations, knowledge workers' productivity was measured by self-assessment, but only a limited number of diaries were collected. The lessons learned can be used as inputs to decision-making processes regarding the design, implementation and management of working environments in higher education settings. Few studies have been conducted concerning the spatial preferences and needs of knowledge workers in universities of applied sciences. The results show that the physical dimension (comfort and layout) is more important for collective productivity, whereas individual productivity is more strongly influenced by the social dimension (interaction and distraction).

Keywords: knowledge work, work environment, higher education, satisfaction, perceived productivity

INTRODUCTION

In order to increase its position in the world economy, Europe needs to transform into a dynamic, sustainable and competitive, knowledge-driven economy. In the Europe 2020 strategy, research and innovation play a central role. In the Netherlands, one of the governmental measures to strengthen the knowledge economy is the transformation of institutes for higher professional education into universities of applied science (UASs). Before 2001, Dutch UASs were not involved in scientific research. Since 2001, applied scientific research by means of associate professorships within research centres has been part of the core business. In 2012 the 39 Dutch UASs (with approximately 400,000 students) employed approximately 450 associate professors. As shown in Table 1, the top ten UASs have a combined 73 per cent market share.[1] As research into Dutch UASs is relatively new, research groups are still relatively small. The number of students (market share) is not a predictor of research capacity. An associate professor may have 2–3 researchers in a group, with students and lecturers being involved on a project basis. The gross area ranges from 104,365–245,163m^2.[2] The campus concept is uncommon within Dutch UASs.

Table 1   Characteristics of the ten largest Dutch UASs

Ranking based on market share*	Ranking based on research capacity**	UAS	Associate professors in fte	Researchers in fte	Number of buildings	Campus	Gross m^2***
1 (11%)	5	Hogeschool van Amsterdam	15.3	50.5	13	Yes	165,209
2 (10%)	1	Fontys Hogescholen	31.6	72.6	32	No	245,163
3 (8%)	2	Hogeschool Utrecht	23	58.4	12	No	166,868
4 (8%)	3	Hogeschool Arnhem Nijmegen	27.0	53.8	2	Yes	134,651
5 (7%)	8	Hogeschool Rotterdam	15.0	32.6	1	No	149,265
6 (7%)	10	Avans Hogescholen	8.0	24	6	No	120,184
7 (6%)	6	Hanze Hogescholen	15.2	42.7	1	Yes	143,062
8 (6%)	4	Saxion	21.9	58.2	3	No	104,365
9 (5%)	9	Haagse Hogeschool	11.0	36.4	4	No	113,300
10 (5%)	7	Hogeschool Inholland	16.0	36.0	8	No	174,929

Fte, full-time equivalent; UAS, university of applied science

* HBO-Raad (2013) 'Marktaandeel instroom per hogeschool', available at: http://cijfers.hbo-raad.nl (accessed: 25th March, 2013).

** HBO-Raad (2010) 'Brancherapportage Onderzoek 2009/2010', HBO-Raad, Den Haag.

*** Limburg, C. and Oosterwijk, R. (2009) 'Trendrapportage Hogescholen 2009', Capgemini Consulting, Utrecht.

Due to the continuing economic crisis, and global competition, research groups in Dutch UASs are facing the challenge of increasing their contribution to the knowledge economy with declining budgets. The Dutch UAS Council has identified eight critical success factors for the successful development of research in European UASs.[3] Three factors are relevant for facilities management as they are related to the location, layout and comfort of the work environment:

- strengthen the relationship between research and education;
- expand networks and partnerships between education and business; and
- increase the quality as well as quantity of staff and facilities.

The other factors are related to quality management, international exchange of knowledge, benchmarking and focus of the research agenda and allocation of research budgets. As a consequence of these findings, facilities managers need to accommodate a new type of user (researchers) in buildings that are primarily designed and used for the transfer of knowledge in an educational setting. Researchers work in a social context and are primarily focused on sharing knowledge, but research also requires deep concentration, eg for exploration and testing of theories, writing research proposals and extensive data analysis. Furthermore, it is important to make a distinction between *explicit* and *implicit* knowledge. Explicit knowledge is described as 'information', implicit or tacit knowledge as the sum of 'experience, ability and attitude'[4]. Implicit knowledge may exist within one person's mind only, making it particularly challenging to exchange. Accessing and opening up implicit knowledge is complex, but very important in order to achieve innovation in organisations and enable exchange and dissemination of knowledge.[5–6] Knowledge development is a dynamic and phased process in which internalisation of knowledge alternates with sharing knowledge (externalisation) and results in subsequent internalisation of new insights and/or new enriched knowledge. New knowledge develops within individuals[7–9] and is created through complex processes of social interaction that link the tacit knowledge embodied in individuals and the explicit knowledge resources of the organisation.[10]

IMPACT OF THE PHYSICAL ENVIRONMENT

The physical environment plays a vital role in the transfer of knowledge in organisations and space is the third most important factor, after people and technology.[11] Although work and learning styles may vary,[12,13] all knowledge workers share two basic needs related to different phases of knowledge development:[14]

- *Time and space to work in isolation, to think, to analyse and to reflect (internalisation):* Internalisation of knowledge is best supported by an environment that provides silence and privacy,[15] as speech (people nearby, telephone conversations etc) is the most disturbing source of sound,[16,17] which results in a potential 8 per cent loss of productivity.[18]
- *Time and space for interaction with others and for collaboration, to generate and evaluate ideas (externalisation, knowledge transfer):* An open and transparent work space promotes interaction. Research by Aznavoorian and Chevez (2010) shows that the open plan workplace is the best layout for knowledge transfer;[19] while Appel-Meulenbroek (2010) has shown that the

level of connectivity (visual co-presence) in open plan offices is a predictor of the level of knowledge transfer.[20]

Knowledge workers' output is thus determined by both human relations, the physical support of communication and social interaction in the office environment, and the ability to concentrate. A number of studies have shown that levels of communication and concentration are strongly affected by the workplace.[21–30] Statistical analysis by Brill and Weideman (2001) shows that work spaces contribute up to 5 per cent of the perceived productivity of an individual worker and 11 per cent to perceived team performance.[31] According to Batenburg and Van der Voordt (2008), satisfaction with the physical environment contributes significantly to the perceived support of individual as well as team productivity.[32] Maarleveld and De Been (2011) point out that the main predictor of perceived productivity support by the physical environment in offices is the (perceived) ability to concentrate.[33]

PROBLEM STATEMENT, RESEARCH QUESTIONS, HYPOTHESES AND CONCEPTUAL MODEL

Until now very little research has been available regarding the impact of the work environment on knowledge production of researchers in UASs. From the perspective of further development and testing of workplace theory, as well as regarding strategic and tactical decision making in real estate and facilities, it is important to improve an understanding of the spatial requirements of research staff. In Dutch UASs the personnel costs amount to 70 per cent of the budget, compared to 15 per cent for housing. As a consequence, effective interventions in the work environment may add value to the organisation.[34] If organisations such as UASs want to use real estate as a fifth business resource, adding to the traditional resources of people, technology, information and capital,[35] they need to know how the work environment influences knowledge workers' productivity and, therefore, a research project was initiated[36] to address the following question:

> What is the impact of the physical and social dimensions of the work environment on satisfaction and perceived productivity of knowledge workers in research centres of Dutch UASs?

Sub-questions included:

(1) Which activities are being conducted by associate professors and staff members participating in research centres in UASs?
(2) How satisfied are they with their work environment?
(3) What is the effect of the physical and social dimensions of the work environment on (perceived) productivity of associate professors and staff members involved in research?
(4) What is the preferred work environment to support knowledge production and transfer of knowledge?
(5) What is the effect of personal characteristics on satisfaction with the work environment, and on the effect of the physical and social dimensions on perceived productivity?

4

According to Haynes (2007), the work environment has a physical dimension (layout and comfort of the work environment) and a social dimension (level of interaction and distraction).[37] Building on Haynes' theory, the authors hypothesised that both the physical and social dimensions of the work environment affect the production and transfer of knowledge as well as the satisfaction and perceived labour productivity of knowledge workers in research centres in Dutch UASs. Furthermore, it is plausible that the output of knowledge workers in research groups within UASs is influenced by corporate policy (strategic focus, funding etc) and employees' work processes. Finally, the individual needs and preferences of end users were expected to influence satisfaction and perceived productivity. Figure 1 shows the conceptual model.
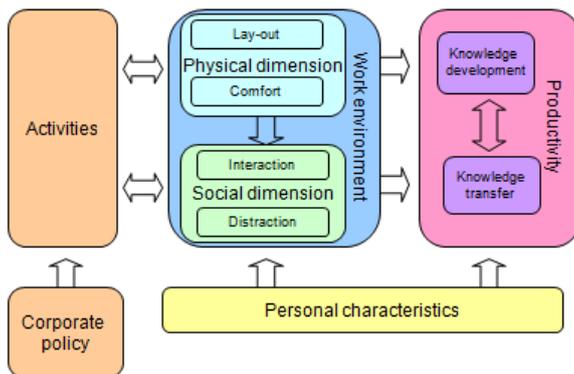

Figure 1 Conceptual model

RESEARCH METHODS

For this research a multiple case study was conducted at Hogeschool Utrecht and Saxion. Regarding research capacity, both UASs are ranked in the top five (Table 1). The study involved six research groups, representing a cross-section of industries: entrepreneurship, technological innovation and healthcare/education. The research groups were accommodated in five separate buildings. The case studies focused on measuring the actual work environment, satisfaction and activities, as well as the perception of end users of the impact of the work environment on labour productivity. Methods included logbook analysis (28 respondents: five associate professors, ten researchers, two research assistants, six lecturers and five students) and in-depth interviews (28 respondents: five deans, six associate professors and 15 researchers); 22 respondents were both interviewed and involved in the logbook analysis. The logbook analysis was linked to sub-question 1 and the in-depth interviews to sub-questions 2, 3 and 4. The deans were included in the interviews to define the context and to answer sub-question 4. In some cases, the dean was also head of the research centre.

To answer research sub-question 5, as well as to verify the case study findings on sub-questions 1, 2 and 3, an anonymous online survey was conducted. The questionnaire was based on the validated work environment diagnostic instrument (WODI-Light), developed by the Center for People and Buildings,[38] as well as the validated work environment survey by Lee and Brand.[39] The questionnaire consisted of 22 questions (measuring activities and place of work/work environment; satisfaction with facilities, building(s), layout, workplace(s), ambiance and comfort;

workplace support of (social) interaction; workplace support of different activities; and perceived workplace contribution to personal productivity and team/organisational productivity) and 23 theses on workplace preferences. This survey was sent to 761 associate professors, researchers and research assistants in 35 Dutch UASs which had appointed at least one associate professor by 2011. The response was 25 per cent (188 responding: 44 lecturers, 132 researchers and 12 research assistants). Table 2 shows an overview of the gender and position of the respondents.

Table 2   Position and gender of survey respondents

| | | Position | | | |
		Associate professor	*Researcher*	*Research assistant*	*Total*
Gender	*Male*	34 (77%)	64 (49%)	3 (25%)	101 (54%)
	Female	10 (23%)	68 (52%)	9 (75%)	87 (46%)
Total		44 (100%)	132 (100%)	12 (100%)	188 (100%)

In the statistical analysis the researchers and research assistants were clustered into one category. After completion of the study, the preliminary findings were presented at EuroFM's European Facility Management Conference 2012 and the International Facility Management Association's World Workplace 2012. This offered an extra opportunity to discuss the findings with facilities managers in order to test the reliability and validity of the conclusions.

RESULTS
The results are presented under five sub-headings:

- activities conducted in the present work environment;
- satisfaction/dissatisfaction with the work environment;
- perceived support of knowledge production and transfer;
- impact of personal characteristics; and
- points for improvement.

Activities conducted in the present work environment
Logbook analysis showed that respondents spent most of their time on concentrated work (approximately 30 per cent), deskwork and administration (30 per cent) and formal meetings (20 per cent). Approximately 10 per cent of hours worked were used for informal encounters and interaction. These results were confirmed by the survey. Although UAS staff worked from home on a regular basis, the UAS building was still their dominant place of work. In traditional work environments (see example in Figure 2), knowledge workers share cellular offices with one or two other colleagues. This office concept predominantly supports the internalisation of knowledge (long periods of concentrated reading, writing and uninterrupted reflection). More recently, designed environments (see example in Figure 3) seem to be more oriented towards externalisation of knowledge and supporting communication and collaboration, in line with a trend to view the office primarily as a meeting place. The case study included three traditional environments — two recently designed ones and one mixed environment (traditional cellular offices with a newly designed informal meeting area). In the questionnaire, respondents were

asked to quantify the percentage of their work time spent in different types of workplaces. The results indicate that approximately 70 per cent of the population works in traditional settings (personal workplace in private or shared office). Approximately 30 per cent of the respondents worked in (activity-based) flexible work environments.

Figure 2 UAS Saxion, Deventer
The Saxion research group 'Hospitality' is accommodated on the second floor. Three associate professors share one room (left); research staff also share a room with three non-allocated desks (right); work space for the research assistants is a little further away in the centre of the building, near the student workplaces.
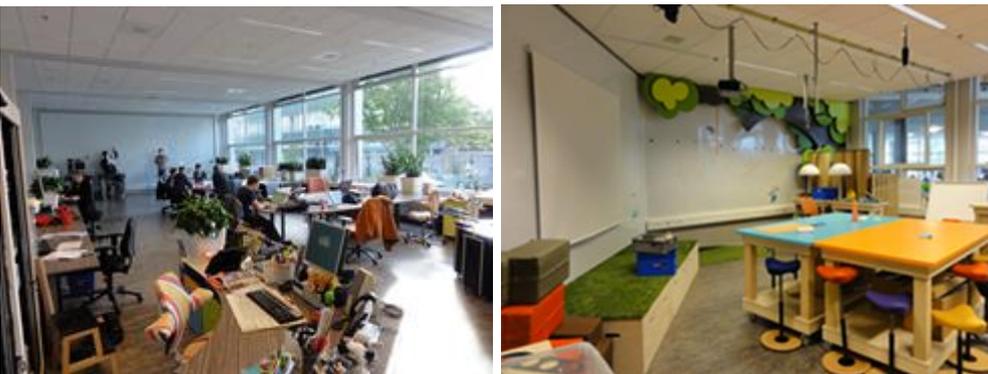

Figure 3 Utrecht UAS
The research group 'Product Design and Engineering' is accommodated on the ground level in the Nature and Technology Building, next to the atrium and close to work spaces for students. Staff members share workplaces at long tables. One of the walls is completely covered by a whiteboard; the tables in front of this board mark the brainstorming area. The photograph on the right shows the creative room for workshops.

Satisfaction and dissatisfaction

None of the physical work environments involved in the study supported all phases of the knowledge development process adequately. The survey results show that the work environment best facilitates 'meetings' and work requiring concentration is least supported; 58 per cent of all respondents reported that their work environment did not adequately support this task. Sharing desks in multiple person rooms correlated with lower satisfaction scores: respondents satisfied with support for concentrated work used a personal desk twice as often as dissatisfied

respondents, whereas dissatisfied respondents used flexible desks in more than six-person rooms seven times more often than satisfied respondents.

The location of the research departments within the buildings seemed to be mainly determined by available space and not by policy. Some were highly visible and situated in the heart of school activities, others were located at the end of corridors or hardly visible due to a location in the basement. Satisfaction with the present location of the individual research groups within the building varied. Visibility, recognisability and proximity to important other functions resulted in a positive appraisal. Many respondents complained about lack of storage space, which is in line with earlier research findings.[40]

The overall picture emerging from the interviews is a gap between the desired and present work environments. The respondents would prefer a work environment that operates as a junction for knowledge — a physical home base where people with a common interest can meet for inspiration while, at the same time, enabling solo work and storage of personal paperwork and resources. As one respondent phrased it during the interview:

> 'At this moment UAS buildings function as crossroads. People cross each other on their routing through the building, but are hardly stimulated to exchange knowledge with people outside their own group.'

Perceived support of knowledge production and transfer

In the survey, respondents were asked to what extent the work environment supported productivity (Figure 4). Respondents answered the questions on a five-point scale, ranging from 'not at all' to 'to full extent', with 3 being the neutral answer. In Figure 4 these responses have been regrouped into three categories: limited (1–2), neutral (3) and great extent (4–5). Figure 4 shows that individual productivity is better supported than collective productivity (team and organisation). Consistent with the case study results, the survey clearly shows that work requiring concentration is not supported adequately. Over 48 per cent of all respondents indicated that they were able to work most effectively in a personal workplace (1:1) and nearly 31 per cent of all respondents indicated they worked most effectively at home. Interviews showed that the perceived effectiveness of working at home was related to the level of disturbance that respondents experienced at the office.
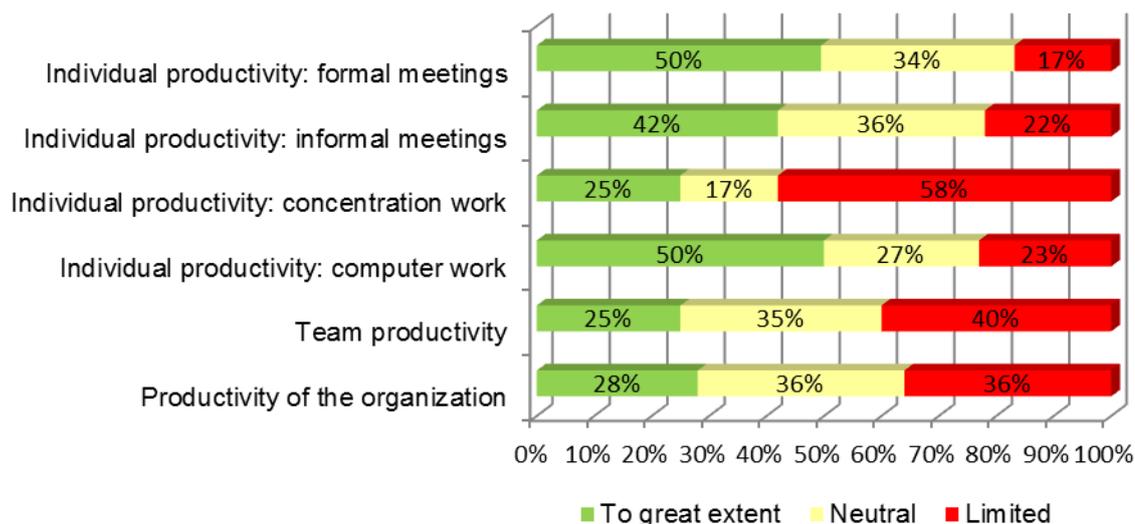
Figure 4 Perceived support of individual, team and organizational productivity

The states of mind associated with work requiring concentration and those associated with interaction are quite opposite. Concentrated work was associated with serenity, harmony, peacefulness, quietness and the colour blue. States of mind that were attributed to communication were: inspiration, creativeness, playfulness, vibrancy, dynamics, upbeat, cosy, warm and the colour red.

Many employees had limited autonomy as to where and when they worked as a result of bureaucracy and management culture, which is not in line with new ways of working. Still, a significant number of respondents indicated that they worked at home quite often (mostly as overtime at night) as they could not reach deep concentration in the office. The survey results indicate that perceived productivity dropped when work spaces were shared with others, with flexible workplaces being least valued in this respect. Figures 5 and 6 show the survey results of the effect of (satisfaction with) physical and social dimensions of the work environment on perceived individual productivity and on team and organisation productivity. The physical dimension construct is based on Haynes (2007).[41] It includes the satisfaction of respondents with ventilation, heating, natural lighting, artificial lighting, décor, cleanliness, overall comfort, physical security, informal meeting areas, formal meeting areas, quiet areas, personal storage, general storage and work area (desk and circulation space). Initially, privacy was included in the physical dimension construct; however, as a result of *t*-testing 'privacy' shifted to the construct social dimension (distraction) to improve internal consistency. Therefore, the social dimension construct (cf. Haynes, 2007[42]) includes satisfaction of respondents with opportunities for social interaction, work interaction, creativity of the physical environment, overall atmosphere, position relative to colleagues, position relative to equipment, overall office layout and refreshments, interruptions, crowding, noise and privacy.
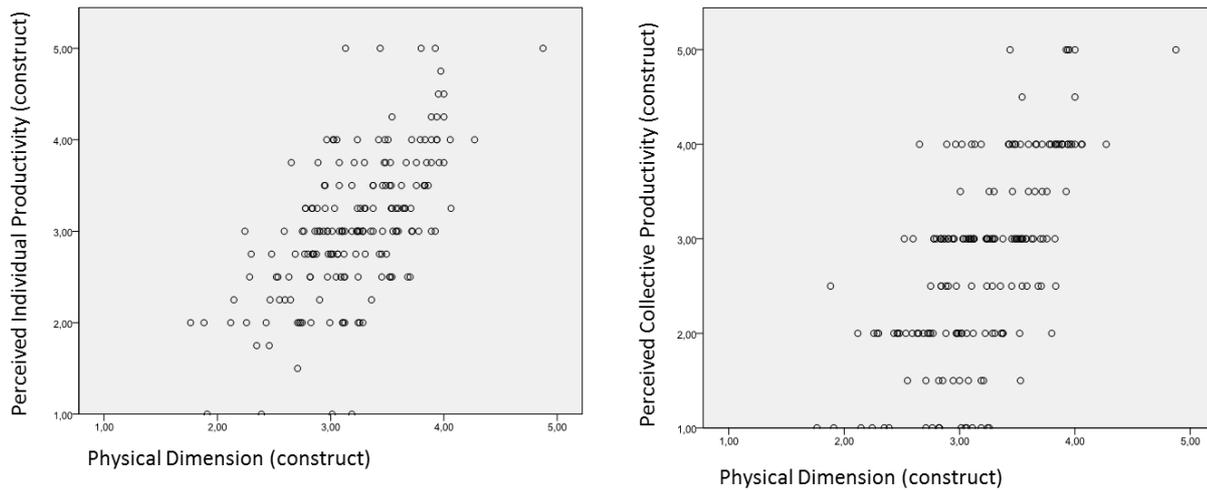
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Figure 5 Scatter plots of the effect of (satisfaction with) physical aspects of the work environment on perceived individual productivity (left) and perceived team/organizational productivity (right)
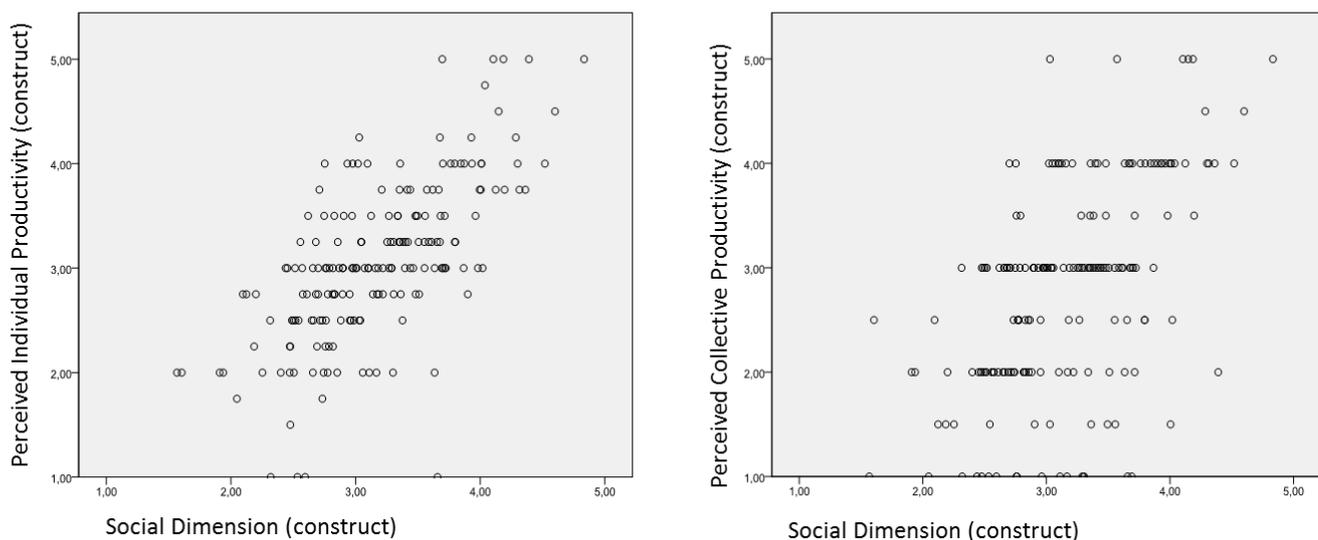

Figure 6 Scatter plots of the effect of (satisfaction with) social aspects of the work environment on perceived individual productivity (left) and perceived team/organisational productivity (right)

The results show a significant correlation between both the social and physical dimensions and collective and individual productivity. Individual productivity correlates more strongly with social aspects than with physical aspects (beta value 0.579, significance 0.000 versus 0.527 for physical aspects, significance 0.000). Collective productivity is more strongly connected with physical aspects of the work environment than with social aspects (beta value 1.026, significance 0.000 versus 0.357 for social aspects, significance 0.003). The physical and social aspects together explain 51 per cent of the variance of perceived personal productivity and 44 per cent of the variance of perceived collective productivity. With respect to both individual and collective productivity, the positive effect of interaction is stronger than the negative effect of distraction.

Layout has a stronger effect than comfort (beta value 0.486, significance 0.000; versus beta value 0.296, significance 0.000).

Impact of personal characteristics

The interviews presented a varied spectrum of what people require in order to be optimally productive. There are considerable differences in the way people work and learn, although none of the personal traits (gender, age, generation, function and type of knowledge worker) showed a significant correlation with the relationship between the social/physical dimensions and perceived personal and collective productivity. Some striking individual differences came to the fore, resulting in a high intragroup variation.

Building on Greene and Myerson (2011),[43] the authors asked the respondents to indicate whether they perceived themselves to be merely an anchor, connector, gatherer or navigator. Forty-six per cent of all female respondents and 27 per cent of all male respondents characterised themselves as an anchor. Anchors strongly adhere to their own workplace, due to both their personal attitude (need for territorial privacy, work style) and their activities (focus on concentration, sensitive to distraction). Anchors often use the same place. In order to meet others they are willing to use facilities which are closer to colleagues rather than their private workplace. Connectors (female respondents: 27 per cent, males: 34 per cent) are often busy with interaction, not only within their team but also with people from other teams and departments. They prefer to use different types of workplaces and facilities all over the building. Gatherers and navigators (combined representing 39 per cent male respondents versus 27 per cent female) are more outside-oriented. Gatherers are involved in many contacts outside the building, at client locations or social venues. For them the office is mainly a place for reflection, either individually or with other people. They strongly need places for concentration. Navigators are more or less visitors to their own office. They most strongly adhere to freedom of choice, an inspiring environment, flexibility in time and place, meeting space and visual privacy. A paired comparison of 'the anchor' with 'the connector' and 'the gatherer' showed a significant effect of gender (Pearson chi-square significance 0.025 and 0.035, respectively).

Points for improvement

The case interviews and the survey show that both the physical aspects and the social aspects of the work environment should be improved to increase employee satisfaction and (perceived) productivity of researchers. Most often mentioned (both in interviews and in the survey) areas of improvement were:

- quietness in relation to occupancy rate;
- reduction of disturbance;
- personal and general archive and accessibility of scientific sources;
- workplace concept; and
- indoor climate.

Lack of storage space and limited access to scientific sources were frequently mentioned problems of the present situation. The respondents preferred more individual workplaces, better opportunities for personalisation of workplaces and more group work spaces for researchers.

REFLECTIONS AND CONCLUSIONS

The physical work environment may have a facilitating role in retaining and attracting the right people and in transferring (company) culture. This is not only important for attracting and retaining excellent staff but also — in higher education settings — for persuading students to participate in research programmes. An inspiring research environment also can have a positive spin-off effect on teaching staff and the market. The field research showed that the physical work environment has a substantial influence on knowledge production in research departments, and indicated opportunities for improvement at both the individual and team/organisation levels. These conclusions are based on the perceptions of the respondents and not on quantitative data for actual employee performance; however, the findings from the interviews and the logbooks were confirmed by the survey (triangulation) and discussions of the research findings with facilities managers, indicating the reliability and validity of the conclusions.

Spatial layout

Erlich and Bichard (2008) state that the importance of inwardly directed activities (reflection/concentration) are often underestimated and activities focusing on knowledge exchange (communication and collaboration) are overemphasised.[44] Likewise, work space in Dutch UASs primarily supports informal and formal meetings (transfer of knowledge). Based on the interviews and the survey, the authors conclude that work requiring concentration is not adequately supported. The work environment primarily facilitates the transfer of knowledge during formal and informal meetings. These results confirm the conclusion that a one-sided focus on interaction conflicts with the need for quietness and has a negative impact on individual productivity and knowledge production. In line with literature findings, the survey showed that a majority of the respondents preferred a small individual workplace with an appointed desk and computer, at a quiet location in the building. Although this can be very supportive for individual performance, due to low occupancy rates this might lead to inefficient (and costly) use of space. Besides, this is not the best solution from a knowledge transfer point of view. Neither the dynamics of an open office concept, nor the isolation and privacy offered by a personal office space, are sufficient in themselves to optimally facilitate all phases of the knowledge development process. A similar dilemma can be found in working at home. Although, according to many respondents, working at home supports the need for concentration, too much working at home is not an appropriate solution. It reduces social cohesion and team building and creates distance from students. As such, working at home is not the best solution from a knowledge transfer point of view. Knowledge workers are part of a social network on which they depend and to which they contribute. To perform well, individually, as a team, and as an organisation as a whole, collaboration and interaction are required as well as being able to work in isolation. Therefore, the office itself should facilitate both externalisation and internalisation of knowledge by providing different spatial solutions. The spatial layout should:

- support both in-depth concentration and communication;
- fit the internalisation/externalisation ratio of activities; and
- accommodate the proximity that is essential for collaborative knowledge development.

Informal meeting areas need to be easily accessible (preferably near the entrance) and attractive to stimulate informal meetings between researchers, lecturers and students. Furthermore, work environments need to be sufficiently spacious as too high a spatial density is counterproductive to freedom of choice and will result in knowledge workers working under sub-optimal circumstances. In response to the complaints about lack of storage space, special attention should be paid to providing sufficient archive and storage space.

Multifunctional use of space is a means to improve efficient use of space, ie the combination of concentration area with a library function, and meeting areas that are also used for brainstorming sessions and for relaxing. Project rooms can accommodate research teams working on the same project, but also can be used for concentrated work in small settings. It is important to stimulate the correct use of the different areas by specific interior design emphasising the states of mind that academics associate with these two different activities. Colour, furniture and decoration may be used to express the appropriate atmosphere and impression.

Freedom of choice

As associate professors and their staff greatly differ with regard to their activities and work styles and as such also regarding preferred workplace characteristics to perform optimally, it is important to give them a certain freedom of choice with respect to how, where and when they work. This seems to be a key issue to support individual productivity. An activity-based workplace concept that provides freedom to choose between a variety of different work spaces (open/closed, formal/informal, individual/team etc) seems to fit best with the different stages of knowledge development (concentration, collaboration, sharing etc).

Location of research groups

The location of research groups within the building affects the visibility and recognisability of a research group and as such the profile to students in connection to education. It also influences the chance of meeting interesting people in corridors (informal meetings leading to transfer of knowledge) and defines the degree of perceived bonding (knowledge development and transfer). Based on the research findings, it is recommended that a central and visible location in the vicinity of relevant partners in education (lecturers and students) is chosen, to support the connection with education and business partners. Areas for concentration should be situated at some distance from meeting areas to reduce disturbance, but within sight of the meeting areas to stimulate transfer of knowledge and to support team productivity. This requires high-standard acoustic isolation of those areas for concentration.

FURTHER RESEARCH

The focus of this research was on the physical environment. Rapid technological developments will lead to an increasing importance of the virtual environment. Further research is needed to explore the consequences of this trend. Another issue for further research can be found in some apparently

contradictory and partly counterintuitive findings: the predictive power of social aspects turned out to be higher (0.52) than that for physical aspects (0.475), whereas in a combined regression analysis the beta value of the physical dimension appeared to be higher than the beta value for the social dimension. This might be an indirect effect, but the data are not clear at this point. A third issue for future research is to further explore the correlations of personal characteristics and work styles on the one hand and work styles and preferred work environments on the other, and how to cope with these differences in practice. Finally, more in-depth research is needed into how to define and measure the 'internalisation-externalisation ratio' and how to optimally facilitate both internalisation and externalisation of knowledge in a quantitative way.

REFERENCES

(1) HBO-Raad (2013) 'Marktaandeel instroom per hogeschool', available at: http://cijfers.hbo-raad.nl (accessed: 25th March, 2013).

(2) Limburg, C. and Oosterwijk, R. (2009) 'Trendrapportage Hogescholen 2009', Capgemini Consulting, Utrecht.

(3) HBO-Raad (2010) 'Naar een duurzaam onderzoeksklimaat. Ambities en succesfactoren voor het onderzoek aan hogescholen', HBO-Raad, Den Haag.

(4) Weggeman, M. (1997) 'Kennismanagement, inrichting en besturing van kennisintensieve organisaties', Scriptum, Schiedam.

(5) Nonaka, I. and Takeuchi, H. (2003) 'De kenniscreërende onderneming, hoe Japanse bedrijven innovatieprocessen in gang zetten', translated by Tromp, T. H. J., 3rd edn, Scriptum, Schiedam.

(6) Heerwagen, J. H., Kelly, K. V., Kampschroer, K. and Powell, K. M. (2006) 'The cognitive workplace', in 'Creating the Productive Workplace', Taylor and Francis, New York, chapter 9.

(7) Weggeman, ref. 4 above.

(8) Nonaka and Takeuchi, ref. 5 above.

(9) Heerwagen *et al.*, ref. 6 above.

(10) Nonaka, I. and Kono, N. (1998) 'The concept of "ba": Building a foundation for knowledge creation', *California Management Review*, Vol. 40, No. 3, pp. 1–15.

(11) Aznavoorian, L. and Doherty, P. (2011) 'The forces driving change', in Coles, D. (ed.) 'Work on the Move. Driving Strategy and Change in Workplaces', IFMA Foundation, Houston, TX.

(12) Kolb, D. A. (1984) 'Experiential Learning: Experience as the Source of Learning and Development', Prentice-Hall, Upper Saddle River (NJ), USA.

(13) Van der Voordt, D. J. M. (2003) 'Costs and Benefits of Innovative Workplace Design', Center for People and Buildings, Delft.

(14)   Heerwagen *et al.*, ref. 6 above.

(15)   Morgan, A. and Anthony, S. (2008) 'Creating a high-performance workplace: A review of issues and opportunities', *Journal of Corporate Real Estate*, Vol. 10, No. 1, pp. 27–39.

(16)   Roelofsen, P. (2002) 'The impact of office environments on employee performance: The design of the workplace as a strategy for productivity enhancement', *Journal of Facilities Management*, Vol. 1, No. 3, pp. 247–264.

(17)   Erlich, A. and Bichard, J. (2008) 'The welcoming workplace: Designing for ageing knowledge workers', *Journal of Corporate Real Estate*, Vol. 10, No. 4, pp. 273–285.

(18)   Roelofsen, P. (2008) 'Performance loss in open-plan offices due to noise by speech', *Journal of Facilities Management*, Vol. 6, No. 3, pp. 202–211.

(19)   Aznavoorian, L. and Chevez, A. (2010) 'Knowledge Management', Geyer Fertilizer Research Publication No. 1, Geyer, Sydney.

(20)   Appel-Meulenbroek, R. (2010) 'Knowledge sharing through co-presence: Added value of facilities', *Facilities*, Vol. 28, No. 3/4, pp. 189–205.

(21)   Kaplan, A. and Aronoff, S. (1996) 'Productivity paradox: Work settings for knowledge work', *Facilities*, Vol. 14, No. 3/4, pp. 6–14.

(22)   Brill, M. and Weideman, S. (2001) 'Disproving Widespread Myths about Workplace Design', Kimball International, Jasper, USA.

(23)   Van der Voordt, ref. 13 above.

(24)   Duffy, F. (2005) 'The Impact of Office Design on Business Performance', Commission for Architecture and the Built Environment and British Council for Offices, London.

(25)   Haynes, B. P. (2007) 'Office productivity, a theoretical framework', Journal of Corporate Real Estate, Vol. 9, No. 2, pp. 97–110.

(26)   Haynes, B. P. (2007) 'The impact of the behavioural environment on office productivity', Journal of Facilities Management, Vol. 5, No. 3, pp. 158–171.

(27)   Haynes, B. P. (2007) 'Office productivity, a shift from cost reduction to human contribution', Facilities, Vol. 25, No. 11, pp. 452–462.

(28)   Haynes, B. P. (2008) 'Impact of workplace connectivity on office productivity', Journal of Corporate Real Estate, Vol. 10, No. 4, pp. 286–302.

(29)   Appel-Meulenbroek, ref. 20 above.

(30)   Van der Voordt, T. and De Been, I. (2010) 'Werkomgeving: Breinbreker of tevredenheidsgenerator?', in Bakker, I. (ed.) 'De Breinwerker', Uitgeverij FMN, Naarden, pp. 67–86.

(31)   Brill and Weideman, ref. 22 above.

(32)   Batenburg, R. and Van der Voordt, D. J. M. (2008) 'Do facilities matter? The influence of facilities satisfaction on perceived labour productivity of office employees', paper presented at the European Facility Management Conference 2008, 10-11 June, Manchester.

(33)   Maarleveld, M. and De Been, I. (2011) 'The influence of the workplace on perceived productivity', paper presented at the European Facility Management Conference 2011, 23-25 May, Vienna.

(34)   Jensen, P. A., Van der Voordt, T. and Coenen, C. (eds) (2012) 'The Added Value of Facilities Management: Concepts, Findings and Perspectives', Centre for Facilities Management and Polyteknisk Forlag, Lyngby, Denmark.

(35)   Joroff, M., Louargand, M., Lemert, S. and Becker, F. (1993) 'Strategic Management of the Fifth Resource: Corporate Real Estate', Industrial Development Research Foundation, Atlanta, GA.

(36)   Van Sprang, H. (2010) 'Van Kenniskruispunt naar kennisknoopunt', MSc dissertation, Greenwich University, London.

(37)   Haynes, ref. 25 above.

(38)   Maarleveld, M., Volker, L., van der Voordt, D. J. M. (2009) 'Measuring employee satisfaction in new offices — The WODI toolkit', *Journal of Facilities Management*, Vol. 7, No. 3, pp. 181–197.

(39)   Lee, S. Y. and Brand, Y. L. (2005) 'Effects of control over office workspace on perceptions of the work environment and work outcomes', *Journal of Environmental Psychology*, No. 25, pp. 323–333.

(40)   Van der Voordt, D. J. M. and Van der Klooster, W. (2008) 'Post-occupancy evaluation of a new office in an educational setting', CIB report 315, Proceedings of the CIB-W070 Conference on Facilities Management, Heriot Watt University, Edinburgh, 16–18th June, pp. 579–588.

(41)   Haynes, ref. 25 above.

(42)   *Ibid*.

(43)   Greene, C. and Myerson, J. (2011) 'Space for thought: Designing for knowledge workers', *Facilities*, Vol. 29, No. 1/2, pp. 19–30.

(44)   Erlich and Bichard, ref. 17 above.