NordDesign 2006
August 16 – 18, 2006
Reykjavik, Iceland

Investigating mobile Knowledge Management support in Engineering Design – an empirical study

Christopher L. Spiteri and Jonathan C. Borg
Department of Manufacturing Engineering,
University of Malta
chspit@eng.um.edu.mt, jjborg@eng.um.edu.mt

Abstract
This research aims to understand the mobile knowledge management support requirements of engineering designers engaged in *mobile* work situations. The findings of this research contribute to a better comprehension of how engineering designers carry out design tasks away from a knowledge base, and how these designers can be better supported throughout the product lifecycle. This paper describes the findings of an empirical study carried out with practicing engineering designers working in the area of product development.

Keywords: mobile Knowledge Management, empirical study

1 Introduction
Engineering design is regarded as a knowledge-intensive activity [1, 2], and managing it is an important concern for the engineering design industry [3]. The main motivation behind this is the ever-increasing expectation from companies to deliver high quality products at shorter lead times and lower costs. This can be achieved by adopting a knowledge management (KM) approach to systematically structure expertise and make it more accessible and easily shared. According to Holsapple and Joshi [4], the main objective behind knowledge management is *"to ensure that the right knowledge is available to the right processors, in the right representations and at the right times, for performing the knowledge activities"*.

Although various KM systems have been developed in engineering design, *mobile* Knowledge Management (*mKM*) has not yet been investigated within the engineering design field [5]. Research work at the Concurrent Engineering Research Unit (CERU) within the University of Malta is in fact being carried out in order to investigate and support the role of mKM in engineering design.

2 Problem Background
Due to the increased globalisation, designers and design teams are now more distributed than ever [6]. Engineering design is a complex task in itself [7], and maintaining collaboration between distributed design teams is very important as the design and development of complex products cannot be done by individual experts [8]. This communication aspect between *distributed* design teams has already been investigated by various researchers, such as Grieb and Lindemann [9] and Troxler and Louche [10], to name but a few. These investigations identify how *distributed* design teams are supported efficiently. However, knowledge support to engineering designer who are distributed as well as *mobile* has not yet

been investigated. It has already been established that engineering designers are frequently *mobile*, i.e. carrying out design-related tasks away from the design office [11, 12]. Such situations result in lack of support whenever a critical decision needs to be taken.

As defined in [13], mobile Knowledge Management (*mKM*) incorporates portable devices (such as mobile phones, PDAs, pocket PCs, tablet PCs and wearable computing) in the field of KM. Mobile technologies can be used to convey relevant knowledge directly to designers away from the office as it would be possible to capture and exploit important knowledge elements anywhere and anytime in any way convenient to the engineering designer.

It has already been observed by the authors in [5] that no such mKM systems that support engineering designers in *mobile* situations exist, and a conceptual framework was developed as an initial reference position. However, in order to further optimise the framework, an empirical study has been carried out in order to identify the extent of mobility of engineering designers, and their activities and knowledge support required when engaged in mobile work. The findings, which are disclosed in the next section, will help to closely map the developed framework with the real-world requirements of engineering designers engaged in *mobile* work.

3 Research Methodology

The general purpose of this research was to identify how frequently do engineering designers work away from the design office, and what knowledge support relevant to their current task is required. The research also identifies the preferred format of the provided knowledge support and the preferred portable device to be used to convey this knowledge support. This was done by conducting a survey whereby data regarding engineering designer attitudes towards mobility and the type and format of the knowledge support required was gathered and statistically analysed.

Following the standard approach of performing research studies [14, 15], engineering designer perceptions and related variables were measured in terms of Likert-type scales, semantic differential scales, multiple choice questions and open ended questions.

The sample of the survey was made of practicing engineering designers and project managers working in product development from different parts of the world. A questionnaire designed and pre-tested according to standard statistical approaches was uploaded online, and its URL link was forwarded to 137 such individuals, whereby 51 meaningful responses (38%) were obtained. The participants of the questionnaire came from the UK, USA, Canada, Denmark, Germany, Italy, Belgium, Australia, New Zealand, and India.

The data obtained from the questionnaire carried out is *ordinal data*, which means that the data has an implicit ordering, and the difference between categories is variable and has no implicit numeric value. Furthermore, the software packages that were used for data analysis were SPSS v13 and Microsoft ® Office Excel 2003.

4 Empirical Results and Interpretation

This section discloses the results obtained from the empirical study, where the most relevant findings are presented. Results include the knowledge support required both when in and away from the design office, the participants' preference in portable devices and the format of the provided knowledge support.

4.1 Knowledge support requirements when working in a design office

From Figure 1a it can be observed that most engineering designers require knowledge support when working on a design project in their office. Throughout the questionnaire, *"Very Often"* was specified as *more than 10 times a week*, *"Often"* was specified as *between 5 and 10 times a week*, *"Sometimes"* was specified as *less than 5 times a week*, whereas *"Rarely"* was specified as *between 1 and 3 times a week*. It can be observed that from the 51 participants, no one answered *"Never"* from the five-point Likert scale, which implies that even the most experienced engineering designers knowledgeable on the subject matter encounter situations whereby knowledge support is required. From the sample proportion ($\bar{p}$), the actual proportions p of the population were inferred with 95% degree of confidence.

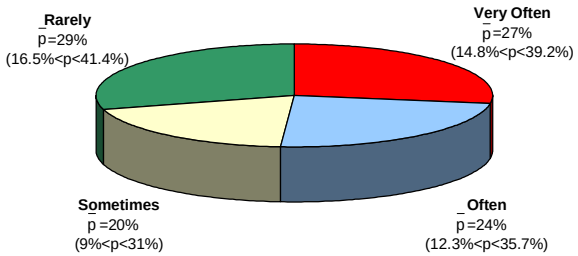

Figure 1a. Knowledge support required when working on a design project in the office

The participants were asked to choose from four types of knowledge support arranged in another five-point Likert scale format: explicit knowledge in the form of CAD drawings and design process/product knowledge; and knowledge that is not articulated and can only be obtained directly from design experts (i.e. tacit knowledge). There was also an allocated optional entry for any other type of knowledge support not listed in the questionnaire. Design *product* knowledge is concerned with the artefact to be designed (such as product specifications and associated design data), whereas *process* knowledge is concerned with the activity of designing itself (such as knowledge about how to carry out tasks and approach problems) [16].

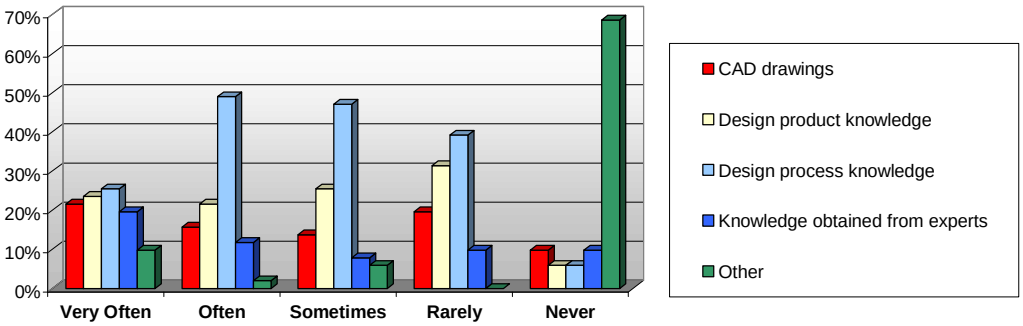

Figure 1b. The preferred type of knowledge support (N=255, $\chi 2$=133.8, p<0.001, df=16)

To investigate what type of knowledge support is mostly preferred by the participants, it was first hypothesised that there is no significant association between the preferred type of knowledge support required and the respective frequency of use (i.e. the null hypothesis H_0). The p-value of the Chi-squared (χ^2) test performed on the results shown in Figure 1b was negligible (i.e. p<0.001) and was less than the level of significance (p=0.05), therefore the null hypothesis H_0 was rejected. Hence the alternative hypothesis that there is a significant association between the type of preferred type of knowledge support required and its respective frequency of use was accepted. It can be observed that the most preferred

knowledge support is *design process knowledge*, i.e. knowledge concerned with the activity of design itself. Other types of knowledge support that were added by the participants included case studies and material properties.

4.2 Leaving the design office to conduct design-related work

Figure 2 represents a pie chart indicating how often participants leave the design office to conduct design-related work. It can be observed that more than half the participants leave their office *between one to three times every week* (i.e. *"rarely"*). However, 40% of the subjects do leave their office to do design-related work on a more frequent basis.

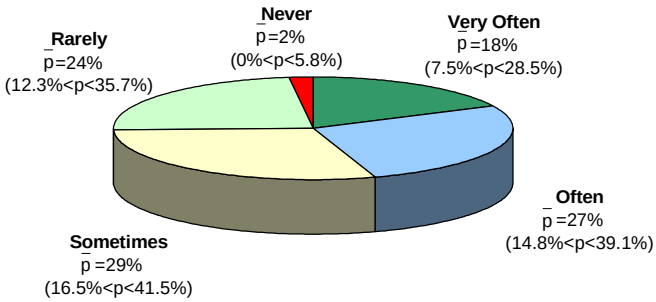

Figure 2. Leaving the design office to conduct design-related work

The participants were also asked to mention the different design-related activities that they perform when they leave the office. The most carried-out activities that designers perform when out of the office are listed in Table 1 below. These activities are grouped in similar categories, where it can be seen that most of the activities are in the form of meetings.

Table 1. Design-related activities performed when out of the office

Category	Activities	Percentage
Meetings	§ Customer/Client interaction, discussions, meetings, interviews, visits, talking about requirements and providing market support § Expert interaction § Work with other designers, colleagues regarding project/engineering § Discussions with suppliers to purchase components	38%
Manufacturing	§ Manufacturing related activities (factory floor), Explaining the design to the manufacturer, Defending our design ideas and related product development when discussing with manufacturer § Project/manufacturing follow-up	23%
R&D, Testing	§ Laboratory: Testing prototypes, FEM tests, material testing and inspection, view new prototyping methods § Research: market, product	17%
Brainstorming	§ Making notes/designs in a different environment, brainstorming, making design briefs, working on new designs § Reviewing designs with the marketing team § Problem solving and updating of existing design.	14%
Other	§ Presentations § Conferences, Trades shows, Exhibitions	8%

4.3 Knowledge support requirements when being mobile

As can be seen in Figure 3a, the majority of designers declare that they do require knowledge support when being *mobile* (i.e. when working on a design project away from the office), and only 4% of the subjects state that they never require any type of knowledge support when being mobile.

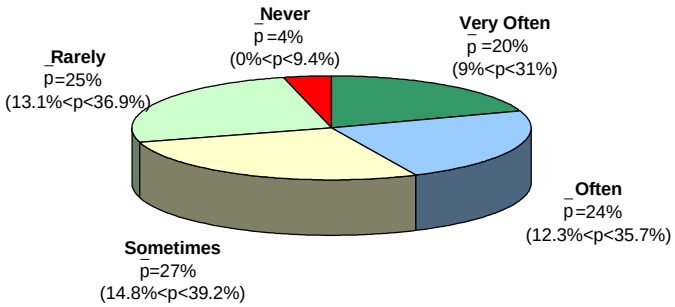

Figure 3a. Knowledge support requirements when being mobile

It can be observed from Figure 3b that *design process knowledge* is still the most preferred type of knowledge support required, as was the case with engineering designers conducting design-related work in the office.

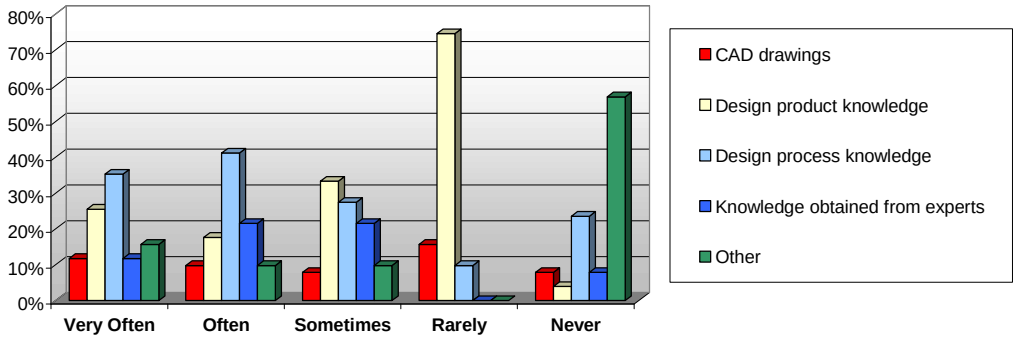

Figure 3b. Type of preferred knowledge support when being mobile (n=255, $\chi 2=128$, $p<0.001$, $df=16$)

4.4 User preferences

When asked if designers would consider using a portable device, more than 70% of the participants showed interest. However, 22% were not sure, whereas 6% replied that they definitely would not consider using a mobile device. The participants were then presented with a list of portable devices in a semantic differential scale format and asked to indicate their preference as to what mobile device they would use, the results presented in Figure 4.

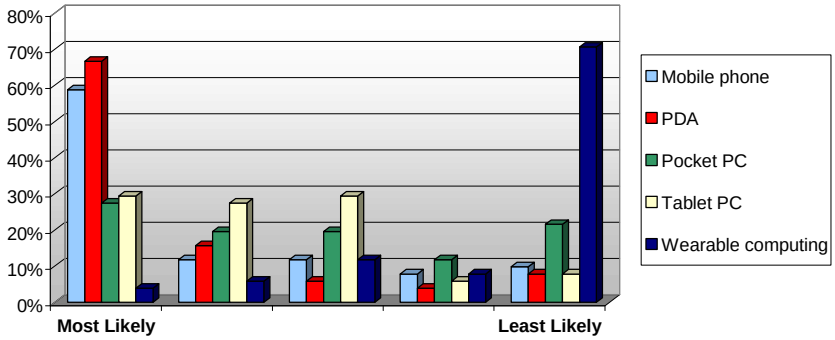

Figure 4. Preferred portable device for mobile knowledge support

Personal digital assistants (PDAs – handheld computers with many capabilities of modern desktop PCs) and mobile phones were the most popular, the least being wearable computing devices (communication devices that can be worn effortlessly and operated hands-free). The fact that mobile phones and PDAs were the most preferred devices may be due to the popularity of these devices, as wearable computing is not yet a popular communication technology.

The participants were also asked to indicate their preference as regards to the format of the supported knowledge. Presentation of the provided knowledge support is very important as this directly influences the effectiveness of the provided knowledge support. It can be deduced from Figure 5 that knowledge support is mostly preferred in multimedia format, whereas audio was the least preferred format. This preference can be attributed to the fact that multimedia supports the interactive use of text, audio, still images, video, and graphics simultaneously.

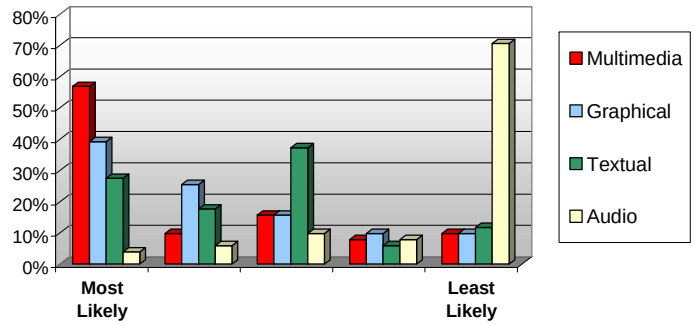

Figure 5. Preferred format of knowledge support provided on portable device

In order to get an indication of whether engineering designers are willing to use a mKM tool to support them when engaged in a mobile work situation, the majority of the participants (84%) declared that they are willing to consider such a tool (Figure 6). This positive attitude towards mobile knowledge support suggests that designers are in fact in need of mobile knowledge support, and a mKM tool will aid in providing such assistance.

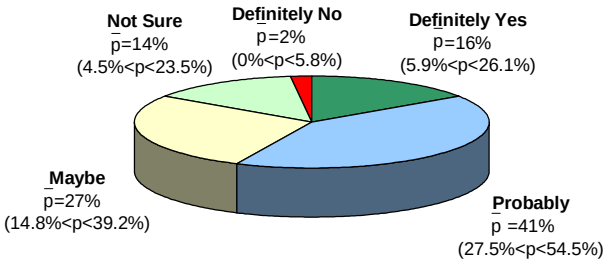

Figure 6. Designers considering using a tool which provides mobile knowledge support

4.5 Correlation tests

Two correlation tests were carried out to identify the extent of the association between the years in design and (a) out-of-office activity, and (b) knowledge support required when being mobile.

Figure 7 shows a stacked bar chart to examine the relationship between the years in design and the frequency of design-related activities carried out of the office. It can be observed that novice engineering designers are more mobile than experienced engineering designers. Novice engineering designers (i.e. with less than 5 years of experience working in engineering design [17]) require knowledge support much more frequently than experienced designers (i.e. with more than 8 years experience working in engineering design [17]).

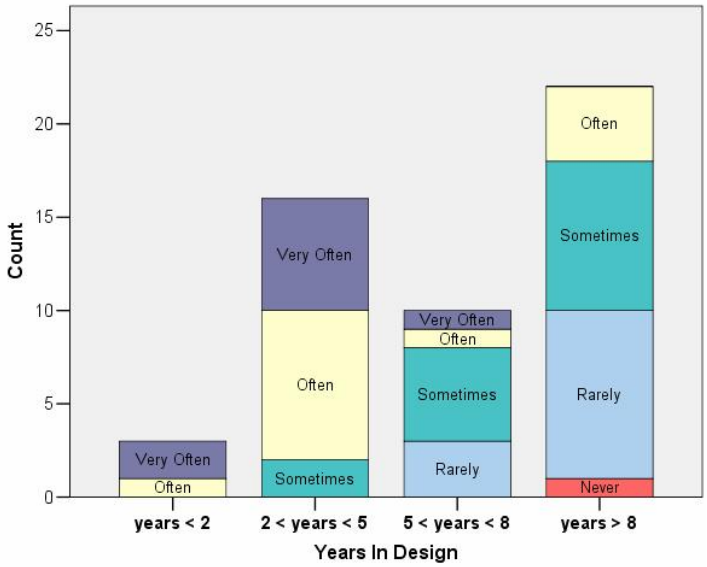

Figure 7. Correlation between years in design and out-of-office activity

A negative correlation (association) can be observed between the designers' number of years in design and out-of-office activities. This is statistically proven by using Spearman's rank correlation test for non-parametric data, since the variables were measured at the ordinal level. The result that emerged from this test indicates a correlation value of ρ = -0.673. A correlation coefficient ranges from negative one to positive one. Hence a -0.673 value indicates a moderately good *negative* correlation (i.e. association) between the two variables. This correlation is significant at the 0.01 (1%) level.

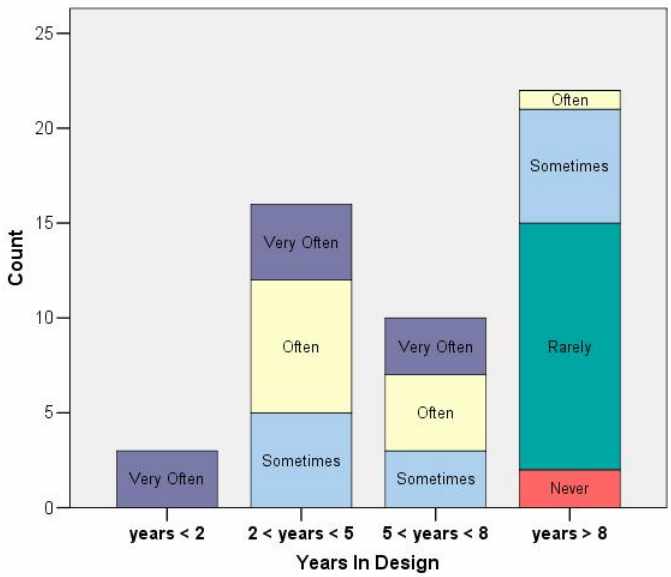

Figure 8. Correlation between years in design and knowledge support required by engineering designers performing design work out of the office

Figure 8 indicates a more pronounced negative correlation than the previous one, where it is strongly emphasised that novice engineering designers require more knowledge support when being mobile than experienced engineering designers, as expected. This is statistically proven by using Spearman's rank correlation test for non-parametric data, since the variables were measured at the ordinal level. The result that emerged from this test indicates a correlation value of ρ = -0.754. This value indicates a strong *negative* correlation (i.e. association) between the two variables. This correlation is significant at the 0.01 (1%) level.

4.6 Testing the Research Hypothesis

The main research hypothesis of this empirical study can be statistically expressed as follows:

> Null Hypothesis (H_o):
> *"There is no statistically significant relationship between engineering designers situated in mobile situations and knowledge support required in such situations".*
>
> Alternative Hypothesis (H_1):
> *"There is a statistically significant relationship between engineering designers situated in mobile situations and knowledge support required in such situations".*

The chi-squared (χ^2) test was used to test the hypothesis that mobility and knowledge requirements are independent. From the test carried out with SPSS, it resulted that $p<0.05$, so the null hypothesis is rejected. This implies that in fact *designer mobility* and *knowledge support required* are dependent. Figure 9 below depicts the relationship of these two variables.

In order to determine a statistical association between the two variables, Spearman's rank correlation test for non-parametric data was used since the variables were measured at the ordinal level, without making any assumptions about the frequency distribution of the variables. The result that emerged from this test indicates a correlation value of ρ=0.754. As already mentioned, a correlation coefficient ranges from negative one to positive one. So a 0.754 value indicates a strong *positive* correlation (i.e. association) between the two variables. This correlation is significant at the 0.01 (1%) level.

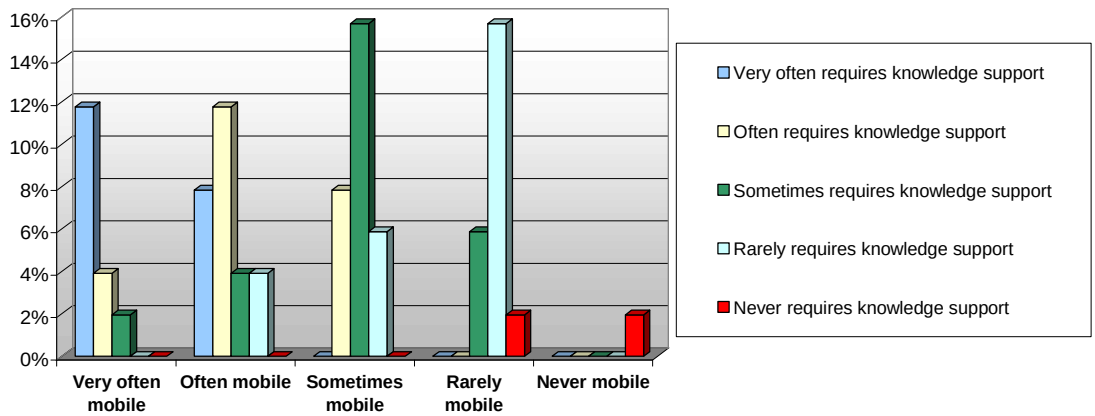

Figure 9. Relationship between engineering designer mobility and knowledge support required

5 Discussion

The findings of the empirical study presented in this paper give important indications of mobile knowledge management support required by engineering designers in mobile work. 96% of engineering designers acknowledge that they require knowledge support when being *mobile*, with design process knowledge being the most required. It was interesting to note that the most design-related activity performed by engineering designers was meetings with other design colleagues, experts or clients.

User preferences clearly indicate that mobile phones and PDAs are the portable devices mostly preferred to be used as knowledge portals, and the format of the transferred knowledge should ideally be multimedia. More than 80% divulge that they consider using a tool which provides mobile knowledge support by using mobile devices, and this favourable result motivates the continuation of further research in mobile Knowledge Management.

The data obtained was further analysed to investigate whether there was a relationship between the designers' years in design and (a) out-of-office activity and (b) knowledge support required when performing out-of-office work. In both cases a negative correlation was observed (the latter being stronger than the former), which indicates that novice engineering designers are more mobile than experienced designers, and knowledge support is required more frequently by novices rather than by experts.

Finally, the research hypothesis of this work was tested by using the chi-squared (χ^2) test with a 95% confidence interval. The result clearly indicates that designer mobility and knowledge support required are dependent. However, the fact that two variables correlate requires further research to actually prove that mobility affects mobile knowledge support requirements. However, the data obtained from the 51 participants provides an insight into the *status quo* of the mobility and the related knowledge support required, especially when one considers that the participants all came from the product development stream.

6 Conclusion

As a result of this empirical study, this paper contributes towards recognising to what extent are engineering designers *mobile*, and also identifies the associated activities and knowledge requirements in mobile work situations.

It is clear that there is a gap in the knowledge support between engineering designers situated in their usual working space and designers performing design work away from their office. From the empirical study carried out it is revealed that many designers are mobile, and most of these designers acknowledge that they need knowledge support in most of the cases. It is through *mKM* that knowledge barriers can be overcome and engineering designers are included in the KM loop.

Needless to say, more work is required at CERU to develop and evaluate a prototype tool that aids designers who are working away from their usual working place.

References

1. Blessing L., Wallace K., *"Supporting the Knowledge Life-Cycle"*, in *Third Workshop on Knowledge Intensive CAD*, 1998, Japan: Kluwer Academic Publishers.
2. MacCallum K.J., *"Does Intelligent CAD exist?"* Journal of Artificial Intelligence in Engineering, 1990, Vol. **5**(2), pp. 55-64.

3. Ahmed S., Hacker P., Wallace K, *"The Role of Knowledge and Experience in Engineering Design"*, in *15th International Conference on Engineering Design (ICED '05)*, 2005, Melbourne, Australia.
4. Holsapple C.W., Joshi K.D., *"A Knowledge Management Ontology"*, *Handbook on Knowledge Management* No.1, ed. Holsapple C.W. (Ed.), 2003: Springer-Verlag, pp. 89-124.
5. Spiteri C.L., Borg J.C., *"Towards a Conceptual Framework for mobile 'Knowledge Management' support"*, in *International Design Conference (DESIGN 2006)*, 2006, Dubrovnik, Croatia.
6. Stetter R., Lindemann U., Pulm U., *"Effective Strategies for Distributed Product Development"*, in *Proceedings of the Sixth Biennial World Conference on Integrated Design and Process Technology (IDPT-2002)*, 2002, Pasadena: Society for Design and Process Science.
7. Song S., Dong A., Agogino A., *"Modelling Information Needs in Engineering Databases using Tacit Knowledge"*, Journal of Computing and Information Science in Engineering, 2002, Vol. **2**(3), pp. 199-207.
8. Barnard Y.F., *"Developing Industrial Knowledge Management: Knowledge Sharing over Boundaries"*, in *International Conference on Advances in the Internet, Processing, Systems, and Interdisciplinary Research (IPSI 2005)*, 2005, Carcassone, France.
9. Grieb J., Lindemann U., *"Design communication in industry: a survey analysis"*, in *15th International Conference on Engineering Design*, 2005, Melbourne, Australia.
10. Troxler P., Louche K., *"Knowledge Management and Learning Culture in Distributed Engineering"*, in *International Conference on Engineering Design ICED03*, 2003, Stockholm.
11. Bellotti V., Bly S., *"Walking away from the desktop computer: distributed collaboration and mobility in a product design team"*, in *Proceedings of ACM Conference on Computer Supported Cooperative Work*, 1996: Cambridge, MA: ACM Press.
12. Kristoffersen S., Ljungberg F., "*Mobility: From Stationary to Mobile Work"*, in *Planet Internet*, K. Braa et al. (eds.), 2000, Studentlitteratur: Lunnd, Sweden, pp. 137-156.
13. Windlinger L., Tazari S., Balfanz D., *"White Paper: Mobile Knowledge Management - Part 2, Individual, Social and Organisational Aspects"*, in *mummy Project (IST-2001-37365)*, 2005.
14. Mitchell M., JolleyJ., *"Research Design Explained"*. Third Edition ed, 1996, Florida: harcourt Brace College Publishers.
15. Langdridge D., *"Introduction to Research Methods and Data Analysis in Psychology"*, 2004, England: Pearson.
16. Hubka V., *"Principles of Engineering Design"*, 1982, Trowbridge: Butterworth & Co (publishers) Ltd.
17. Ahmed S., Wallace K.M., Blessing L.T., *"Understanding the difference between how novice and experienced designers approach design tasks"*, Research in Engineering Design, 2003, Vol. **14**(1), pp. 1-11.