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AN EMPIRICAL STUDY ON IMPROVING THE UNDERSTANDING OF EMAIL RECORDS BY AUGMENTING WITH INFORMATION ON CONTEXT

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ABSTRACT
Email fulfils an important role in facilitating distributed communication in engineering design projects and contributes to the persistent records of the project, but the nature of email communication may mean that records are difficult to understand by those who have not been involved in the projects. This paper presents an investigation into the effectiveness of augmenting emails with contextual information as a mechanism for improving such understanding. The work was part of an investigation into the effectiveness of email as a project communication method including the study of a large corpus of emails from a merchant ship design project and of the team that produced them. The work involved taking samples from the corpus and exploring the ability of readers with and without background contextual knowledge to understand and answer questions on the samples both as original email records and augmented with hyperlinks to contextual explanations. The experiments showed improvement in the understanding of the augmented emails by those with and without contextual knowledge. The experiment design is presented and the findings and their implications summarised.

Keywords: communication, design informatics, information management, email use in design

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1 INTRODUCTION

In an increasingly competitive and global business environment the use, reuse and manipulation of information is becoming a key factor in the success of any product development organisation (Hicks et al., 2002, Hicks et al., 2008). Ensuring that team members are able to access (or are provided with) the right information in a timely manner is one of the key challenges facing organisations (Vaghely et al., 2007, Auricchio et al, 2010). Communication is the process through which this timely provision is generally achieved (Eckert et al., 2001). With the increasingly global economy engineering projects are becoming more geographically distributed. As a result of this, effective communication in some projects is increasingly difficult due to the distances involved, multiple locations and numerous participating organisations. Amongst the most dominant communication methods is email which fulfills an important role in facilitating distributed communication and is thus seen as a key target for improvement (Eckert et al., 2004).

This paper presents the results of an investigation into the effectiveness of augmenting emails with contextual information available to the original authors of those emails as a mechanism for improving the understanding of emails by diverse and changing members of a product development team. The work was carried out as part of a larger investigation into the effectiveness of email as a project communication method including the study of a large corpus of emails and the project team that produced them in an engineering company contributing to the design of a new merchant vessel. The paper begins with a review of the role of email and the results from an interview of practicing engineers on the subject of email use in engineering projects which provide the motivation for the present study. The experimental design of the study is presented in detail and the findings summarized with respect to their implications for the next generation of email systems, record keeping and the training of design staff using these.

2 EMAIL

Despite the rapid growth and widespread use of email it has traditionally been seen as an informal (and perhaps personal) communication tool, perhaps due to the ease with which users were able to exchange messages (Eckert et al., 2004). The overheads associated with communicating over large distance were reduced almost to nothing, and for co-located workers new affordances were provided for example allowing rapid but asynchronous communication and providing a readily accessible and searchable recording mechanism. Uptake in email use has been generally driven not by central organisational pressure but by its popularity with users. The result of this is that many companies do not have central policies to guide employees' use of email or to manage the large collections of email which their employees are producing (Darlington, 2002). Some engineering companies do make use of databases or archives for the storage of email, however, these are rarely intended (or allow) for access, study or reuse of the email content.

Now that email has been established in the workplace for a significant period of time the problems with the current disorganised systems are beginning to become apparent to users and managers Pennock, 2007). The problem which initiated the research reported in this paper concerns the tracking of decision rationale within long life design projects. It is not uncommon for large engineering projects to take decades to transition through the active phase of their life-cycle. During these projects the individuals involved will change, they will retire, be promoted, and move on to other projects. Difficulty in tracking design rationale and decisions throughout the life of the project is one of the immediate effects of this flux of people. It has been suggested that this problem has been compounded by the use of email; if rationale is stored, communicated or developed using email then when an individual employee leaves an organisation the information present in the employee's email may be lost or become difficult to access.

3 INTERVIEW STUDIES

The research reported here is part of a larger study carried out in partnership with a multi-national company (henceforth the Company) that provided an email data set and access to engineers for the purposes of the study. The data set consisted of an email corpus (from a single engineering project) that comprises over 16 000 emails, the associated project documentation and the opportunity to interview 6 engineers involved with the project. The data set contains information pertaining to a

single engineering project which was centred around a series of 6 high value contracts. The Company acted as a major supplier in the production of a series of high value contracts for a large foreign industrial company (referred to as the Customer). Each contract essentially required a replica of the work in the first, tailored to the varying requirements of the end users (referred to as the User).
During the course of the project the Company acted primarily as an integrator negotiating with multiple suppliers (referred to as Suppliers).

3.1. Email Corpus

The corpus consists of 16 000 emails sent over the first 4 years of the project. The corpus represents the email exchanges of 650 senders (1 080 recipients), with approximately 30 of those being core project members (either from within the Company or the Customer). The emails were selected by employees, who either authored the emails within an internal project information management system, or copied emails from their individual email accounts into the system. Entry of email into this management application was explicitly managed and encouraged by the Project Director, who also handled the organisation of documents within the project information system.

3.2. Interviews

A set of 6 interviews with key engineers within the Project were carried out. The interviews were carried out at the Company site, they were semi-structured in nature and lasted for 30-40 minutes each. They were recorded, the recordings were transcribed and findings were elicited. The interviewees were selected to provide broad coverage of the roles within the project. This was to produce a representative view of the different roles within the project rather than to produce a proportional sample across the project. As a result the findings cannot be generalised, they only represent the opinions and perceptions of the interviewees. All of the engineers were still involved with the project in the same capacity, although only 3 were still spending significant time on the project at the time of the interviews. The roles of the interviewees are as follows.

- Project Director: The principal managerial role in the project. Coordinated the Project managers and handled liaising with the Customer.
- Project Manager: Managed the engineering team at the UK site, responsible for several major components of the project.
- Project Secretary: Joined the project to act as logistical support when organising interactions with Suppliers and the customer.
- Service Engineer: Handled in service issues reported by the Customer and the User.
- Warranty Manager: Investigated claims made by the Customer and determine contractual liability and negotiate responsibility and costs attributed to different parties with the Project. He had significant interaction with the Customer and the User.
- Software Engineer: One of the engineers working under the Project Manager. He had only minimal interaction with Suppliers and no interaction with the Customer. This was his first project within this department of the Company, so he was ‘trying to learn [the] systems and tools [and] work on [the Project]’.

3.3 Challenges of email use

The interviews revealed three affordances and three challenges. These include:

A1. The primary affordance of email was consistently described as being its role as a record keeper, both in the sense of keeping incidental records of ongoing communications and also for specific and intentional recording of key points.

A2. A second very important affordance is the speed of communication and response offered by email, particularly in a global project context.

A3. Another important affordance was that of providing a clear communications channel when clarity is critical or the recipient is a non-native speaker.

C1. The Project Director revealed that the problem of knowledge churn was significant in the project, with “almost every name chang[ing] apart from mine”. The impact of this problem can be seen if is related to the point made by three of the other interviewees that when information seeking they commonly rely on other engineers’ understanding of the existence and location of the information they are looking for, rather than using technical retrievals mechanisms.

C2. The Service Engineer described how managing the information flow resulting from regular

activities such as filing field reports was difficult and was not something that was easily supported by email.

C3. That there are cultural differences in terms of the expected sending and response behaviours when communicating with engineers in a different nation.

The references to email as an important record keeping system supported the rationale for the research, that email is both an important communication and information management system and potentially a tool for long-term information storage in the modern engineering environment. The repeated mentioning of the use of people when finding information inspired an investigation to explore how such human driven information seeking could be made more effective using the contextual information already available in the corpora of email. The remainder of the paper describes an investigative study that explores ways of assisting engineers in the finding and interpretation of emails by the particular features of their content (rather than by document characteristics).

4 EXPERIMENT

In response to the identified industrial needs it was proposed that the identification of the conceptual meaning of the content of emails and associated engineering documents would allow for relationships to be identified between email and documents that are relevant to each other; thereby reducing the fragmentation of information within a project. The interview study further identified the need to support the interpretation of emails by those not directly familiar with the context of the project or organisation in which the email were authored. It was proposed that this might be addressed by the augmentation of email by identifying terms within the content of the email and associating them with the associated engineering documents that are most closely related to those terms. The experiment described here was designed to explore whether this proposition was supported by evidence from users presented with a simulation of the tool.

The specific scenario that this experiment aimed to simulate is that of supporting an engineer to (re)use valuable information held within project emails and specifically to interpret the content with respect to the wider project. A hypothetic-deductive approach was taken in the design of this experiment, with the hypothesis "Adding context available to the original authors of emails will improve the ability of other individuals to interpret those emails". This hypothesis was tested by presenting two groups of people a series of emails adapted from the project corpus and then asking a series of questions to test their understanding of the information content of the emails. The participants were a mixture of engineers from the company (who will have had various levels of understanding of the context from their employment) and undergraduate students who had been pursuing an engineering design course. One group of participants (the No-treatment group) was presented with the 'raw' unenhanced emails and the second (the Context group) with augmented emails. From the hypothesis two testable predictions were developed:

1. "The total scores of the Context group will be greater than those of the No-treatment group"
2. "The scores for questions requiring synthesis of information from multiple emails will be more substantially improved in the context group than their scores for questions requiring direct identification of concepts within the emails"

The following sections describe the considerations taken when designing the experimental procedure.

4.1 Experiment design

The experiment was designed around 6 candidate independent and 1 measurable dependent variables identified as influencing or being influenced by the situation being investigated. These are:

- Amount: the quantity of context provided. In terms of link density or length of abstracted text or number of annotations applied. It is expected that this variable will have the strongest influence on the participants.
- Form: the document structure and syntax used to present context, e.g. as hyperlinks to summary documents, as footnotes, as annotations or as abstracts. In this experiment the form the context is represented in was not varied. The context was provided by hyperlinks to summary documents as this is a well established convention that should be familiar to all participants and additionally it was the approach used in a study of the aspect of prior knowledge and working memory on the cognitive load in hypertext reading (Engle et al. 1992),
- Delivery: the technical system used during the experiment, e.g. paper based, an electronic representation of the email, mock email client. The effect of the system used for delivery is not

of interest from the pragmatic perspective; it is largely established what engineering email systems will consist of and thus it will not be varied by the experiment. What had to be considered, however, was the effect of changes to the participants' routines and the novelty of the experimental program.

- Purpose: the type of problem that the participants are posed, e.g. tracing the rationale behind a design decision, identifying the party responsible for a warranty issue. All participants were asked the same set of questions. The questions the participants were posed were designed to require a combination of the identification of facts from within the single emails and to require the interpretation of information across multiple emails.
- Experience: the level of education and career experience of the participant. Participants included a mix of inexperienced students and highly experienced professional engineers. This was controlled for by direct questions about the participants' level of experience in the post-test interview.
- Existing understanding: the level of familiarity with terminology and organisational practice. Again, the participants included a mix of inexperienced students and highly experienced professional engineers. This was controlled for by selecting emails and questions that required no knowledge of the organisations involved, and with direct questions about the participants' level of familiarity with the terminology and the organisations in the post-test interview.
- Information: the information provided by the augmentation process. The type, quality and semantic content of the information provided were controlled as part of the experimental setup.
- Impact on ability to understand: the effect on the ability of the participant to comprehend and correctly interpret the set of email. This was the single dependent variable identified for measurement.

4.2 Variation

In order to test the predictions a single variable - the Amount of context provided to participants - needed to be varied. As such the experiment participants were randomly divided into 2 groups, the Context group and the No-treatment group. The Form, Delivery, Purpose and Information variables were controlled through the experimental design and the Experience and Existing understanding variables were controlled for by direct questions in the post-test interview.

The metric for measuring the dependent variable was designed in advance of the experiment. The robustness of the measurement was improved by implementing multiple measures of the same variable. The different measurements targeted two perspectives of the variable, specifically an objective measurement of the participants' actions during the experiment and a subjective measurement of the perception of the participants. The two measurements used were:

- Qualitative assessment of the participants' answers
- Direct questioning of the participants' perception of the test

The details of the measurements are provided below.

4.3 Meta-evaluation

The following points outline the steps taken in designing and conducting the experiment to ensure the results were accurate, reliable and repeatable.

- Placebo design: any experiment occurs through some set of prescribed arrangement; it has been observed that participants will react to the arrangement of an experiment to the extent that it will affect the results (the Hawthorne effect (Adair, 1984)), although the underlying mechanisms behind the Hawthorne effect are not well understood. A placebo is designed to mimic the experiment without altering any of the identified variables. The results from the placebo group then allow the results to be normalized for the effects of the experimental arrangement. As the variable was the provision of additional information it was satisfactory to use a "no treatment" group to serve as a placebo - in essence a normal control procedure, i.e., all other variables were maintained between the two treatment groups.
- Experimenter controls: a key factor that could have influenced the way participants answered questions in the experiment and thereby affected the verisimilitude of experimental results was hypothesis awareness. Hypothesis awareness is the condition in which participants having a genuine or imagined understanding of the expected outcome of an experiment, which then guides their behaviour (Conway et al., 2005). This is separate from effects resulting from

knowledge of being a subject in an experiment (the Hawthorne effect). Hypothesis awareness was militated against by using software to control the presentation of information to participants and using a script to limit the variation during the interactions between the participant and the experimenter.

- Deviant case analysis: in most sets of results there will be cases that do not support or contradict a pattern that is clearly visible in the data. When dealing with large sample sizes it is possible to demonstrate that these deviant cases are not statistically significant. With small sample sizes it is necessary to be able to identify and explain the factors that resulted in these deviant cases; thereby showing the cases not to be significant. This need to analyse deviant cases was considered in advance to ensure that sufficient information was available to facilitate an effective analysis. To do this, variables that would normally be considered irrelevant had to be recorded; that presented an interesting challenge. The approach taken in this experiment was to conduct interviews with the participants to develop an understanding of their experience and familiarity with the subject matter in the emails.

5 METHOD

Using the understanding of the variables identified, the variation chosen, the measurements required and the considerations given to meta-evaluation of the results the following procedure was designed to meet the requirements of the experiment, advised by a previous study of hypertext reading by DeStefano and LeFevre (2007).

1. An example thread of emails where one of the main participants was still employed by the Company was identified.
2. The emails were augmented in line with the variation.
3. The participants took a Working Memory Test.
4. The augmented and original threads were presented to sample of engineers and a sample of design students using a standard email reading interface and they were asked to interpret the emails.
5. The participants then answered a series of questions based on their understanding of the emails.
6. The participants then completed a post-experiment interview.
7. The participants' answers to the questions were then assessed with reference to the answers provided by the employee involved in the thread.

5.1 Identifying and preparing emails

To identify emails a thread of emails was selected from the corpus of documents provided by the Company. The thread was chosen by the primary author because it represented a concise discussion of a typical engineering change negotiation between engineers in the Industrial Partner, its customer and one supplier.

Due to the sensitive nature of email correspondence the original corpus was made available on the basis that it would be kept confidential and all information published would be anonymised. As such, for those participants from outside the Company it was necessary to produce an anonymised set of emails. However, to ensure the emails remained readable and that anonymised entities (People and Organisations) could remain identifiable from one document to another it was necessary to replace their original names with pseudonyms rather than a more conventional approach of redacting the sensitive information.

The individuals mentioned within the material used in the experiment were made anonymous by consistantly replacing their names' with pseudonyms (generated using Fake Name Generator)

The organisations mentioned were also made anonymous using a similar approach; however, pseudonyms were constructed so their characteristics were similar to those of the original names.

In order to identify objects within the text requiring description, two coders not familiar with the corpus or domain used a grounded approach.

To ensure consistent identification of objects, once an object was identified in one email a stem of that object was used to search for other occurrences of the object. For multiple occurrences within a single document the common hypertext principle of just linking to the first occurrence was followed.

Once all the objects had been identified, factual descriptions were created for each object based on the domain knowledge of the Author, consultation with project documentation and discussions with the

employees of the Company. No references or hyperlinks to other documents or domain specific terms were included within the descriptions to limit the scope for variability in complexity and usefulness between descriptions (Engle et al. 1992).

5.2 Working Memory Test

A Working Memory Test was used to control for the general reading ability of the individual participants (rather than self-reported levels) as well as the current mental state of the individual i.e. to account for hung-over students or fatigued engineers.

Measuring general reading ability has been identified as important for understanding the differences of individuals participating in studies of the cognitive load in hypertext reading (DeStefano and LeFevre, 2007) Participants with Low WMs will perform less well than participants with High WMs. An operation span task working memory test was used, following the procedure outlined by Engle (1992). This was used rather than a more directly appropriate reading span task due to the time constraints and the extra time required for the reading span task; research has suggested that both tasks effectively measure the same underlying cognitive function (Conway et al., 2005).

The operation span task consists of presenting (by means of a moving window) a set of equation and stimulus pairs to the user. The user is instructed to state whether the equation has been correctly evaluated and remember each associated stimulus until the end of the set; they are then instructed to recall the stimuli and their order within the set.

Items are presented by a moving window, with each component of the item being presented on a separate frame of the screen. This was implemented using a simple pdf presentation.

The stimuli used consisted of a pool of 1 syllable words spanning the vowel range, gleaned from a comprehensive word list.

The participants' responses to the test are discussed in section 6.

5.3 Presentation to participants

In line with the intention to control the independent variables Form and Delivery, the emails for both the Context group and the No-treatment group were presented through the same software interface (a standard email client). The emails were formatted as HTML emails to allow for the hyperlinks to the context documents to be inserted in the same way as conventional hypertext links, therefore the only difference between the experimental interface used by the Context group and that used by the No-treatment group was the presence of links within their emails. The context documents were also formatted in HTML, when a participant clicked on a link to a given context document it was opened in a standard web browser.

5.4 Questions

In order to test Prediction 2, multiple questions were set for the participants with Question 1 testing their ability to summarise the factual information in the email thread as a whole. Question 2 tested their ability to extract information just about the change under discussion in the email thread. Questions 3 and 4 further tested their ability to extract factual information about very specific topics. Question 5 tested their ability to synthesise information across all the emails and use their understanding to comment on a significant difference between 2 emails in the thread. The questions presented to the participants are listed below:

- Q1 Summarise the email thread, in less than 50 words.
- Q2 Describe the final state of the change introduced.
- Q3 Name and describe 3 key individuals within the thread.
- Q4 Describe the responsibilities of the different organisations involved.
- Q5 Discuss the difference between the final email from MP and the final email from AC (names given in full in the original question).

5.5 Analysis of answers

Two approaches to the analysis of the answers provided by the participants were followed. First, the questions were answered by the individual who directed the project from which the emails were taken. His answers were used as the standard by which the others were marked. Second, grounded qualitative coding of the answers was performed by a single coder. Based on the approach of DeStefano DeStefano and LeFevre (2007), answers to questions 1, 2 were given a score out of 5, with 1 point

being awarded for each correctly identified concept. Questions 3 and 4 were given a score out of 3, 1 point being awarded for each correctly identified and described person or company. Question 5 was also scored out of 3, with 1 point being awarded for each correctly identified concept.

5.6 Post test interview

Post test interviews were conducted to control for the variable Experience in the participants and to test for hypothesis awareness. A semi-structured interview approach was used, with the interviews with being directed by the following questions:

1. Which degree are you studying for?
2. Do you have any familiarity with hydraulics or power electronics?
3. Have you worked in industry?
4. How did you find the task?
5. Do you think you answered all of the questions satisfactorily?
6. Were there questions that were particularly difficult to answer?
7. Did you trust the information in the emails?
8. During the test, did you come up with ideas for why the experiment is being conducted?

These interviews showed that while a number of the volunteers had worked in industry they had no familiarity with hydraulics or power electronics. They found the interpretation of the technical detail in the tasks difficult, but the entire Context group felt that they were aided by the linked information. Such linking would especially assist service engineers and those revisiting emails a long time after they have been sent.

6 RESULTS

6.1 Working Memory Span

From the answers to the check questions it is clear that all the participants decided to concentrate on just remembering the words, which would have resulted in high levels of errors in the check questions. Additionally, none of the participants were observed using short term memory techniques to improve their recall. From these 2 results we can infer that the participants took the exercise in good faith and that their answers when recalling the words are a genuine reflection of their performance in the test.

The Working Memory Spans are plotted against the Answer scores in Figure 1, from which it can be seen that there is no clear correlation between a participant's Working Memory Span and their ability to answer the questions. As there is no correlation evident the Working Memory Spans will not be part of the further analysis of the answers.

6.2 Answers

Table 3 shows the working memory scores and average answer scores as a percentage for each participant, together with an indication of which participants are in the Context group (participants A, C, D, E, L, M, O, P, Q). Figure 2 shows the individual scores for each participant for questions 1-5. The answers were analysed using the method described above. The average score across all the participants was 57 %. The average score for the Context group was 60 % and 48 % for the No-treatment group.

Participants N, O, P, Q and R were experienced engineers; they had an average score of 71 %, relative to an average of 50 % for those without experience. There are too few participants with experience to make claims about the effect of the provision of context on experienced engineers. However, the average score of the experienced engineers in the Context group was 80 % relative to 57 % in the No-treatment group.

The average score for participants without experience in the Context group was 55 % and 45 % for participants in the No-treatment group.

The results of the Working Memory Span test showed no evidence for a correlation with the participants' ability to answer the interpretation questions. This result suggests that future experiments on the topic of engineers' ability to interpret emails will not benefit from controlling for readability using the operation span task type of test for Working Memory Span.

The results of the Intepretation task clearly show that the provision of context to engineers improves their ability to interpret emails. Although this result is maintained for engineers with experience further experiments are needed to be able to establish this conclusively.

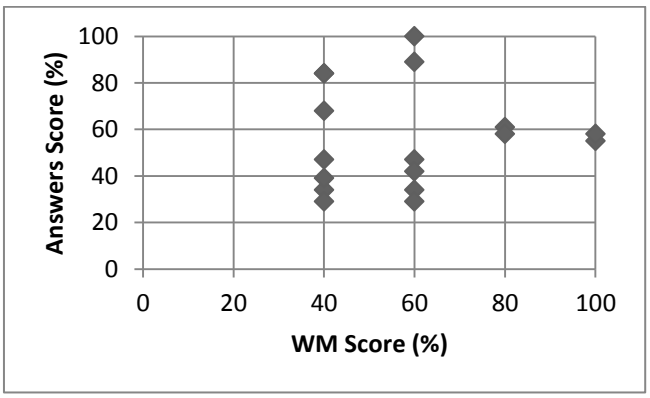

Figure 1.: Normalised Working Memory Spans against normalised Answer scores

Table 3. The Working Memory Span and Answer scores for each participant.

Participant	WMS Score (%)	Answers Score (%)	Context provided
A	60	89	✓
C	40	68	✓
D	80	61	✓
E	60	47	✓
f	60	34	
g	60	42	
h	40	47	
i	80	58	
j	40	34	
k	100	55	
L	40	39	✓
M	60	29	✓
n	40	29	0
O	60	100	✓
P	40	84	✓
Q	100	58	✓
r	40	84	

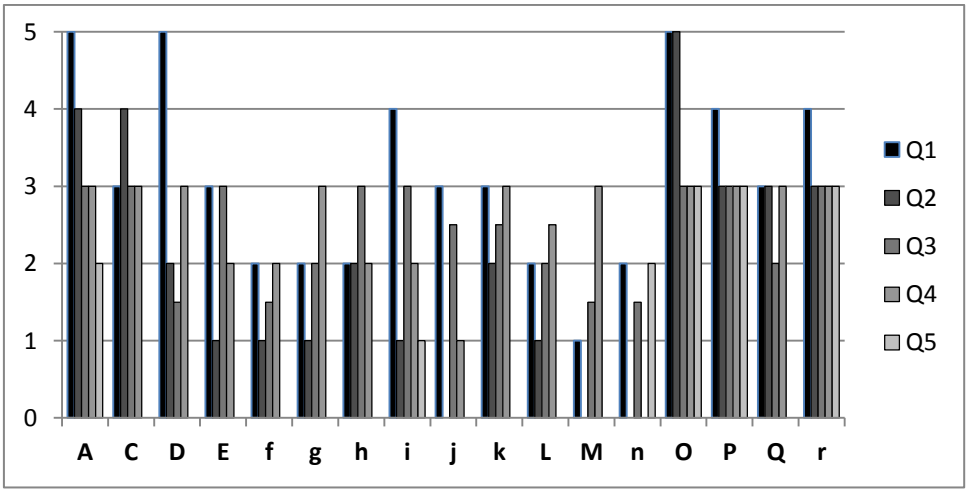

Figure 2. The participants' individual scores for Q1-5 (upper case shows Context group)

7 CONCLUSIONS

This paper has introduced the challenges of working with email in a design context, and has described a programme of research with an industrial partner exploring the use of email in a multi-national engineering project. It was described in particular an experiment to explore the merits of adding contextual expansion of emails via embedded hyperlinks to explanatory material as a means of assisting the understanding of emails especially to those not familiar with their content. The results show an improvement in the understanding of email both by those with prior understanding of the industry context and those with no such understanding. The work has implications for the design of email systems but also for the training of users.

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