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ABSTRACT

Because of the crucial nature of the technical literacy problem and the necessity for employees to be able to understand and apply information contained in technical manuals, a technical literacy test was developed in order to identify the level of a person's familiarity with or likely aptitude for work using a computer. The information yielded by such a test would not only be used to determine an individual's current computer literacy as measured by industry standards, but also would serve as a basis for identifying further training needs. To this end, a program written in HyperCard for the Macintosh computer was developed to test the computer skills of 180 school leavers and 190 industrial labor workers. The 25-minute task tested skills of using a mouse, keyboarding, and ordering parts for a Lego construction. Results of the test indicate that the students performed better than the industry employees, and that males performed better than females. These results are attributed to the greater familiarity of males with computers, particularly in school, where the differences in scores were particularly significant. Several conclusions may be drawn from the test, including those concerning gender differences, predicting computer aptitude, and providing technical education. (5 references) (Author/DB)

# The Technical Literacy Project: a comparison of computer literacy skills among school students and employees in industry.

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# The Technical Literacy Project: a comparison of computer literacy skills among school leavers and people in the workplace.

**Abstract:**

A program written in HyperCard for the Macintosh computer was developed to examine the computer skills of 180 school leavers and 190 workers in industry. The 25-minute task tested skills of using a mouse, typing information, and ordering parts for a Lego construction. In general, school students performed better than the workers in industry, and males better than females. These results are attributed to the greater familiarity of males with computers, particularly in school, where differences in scores were particularly significant.

## Background to the project

The growing complexity of modern industry means that the ability to understand and correctly apply the information in technical manuals is becoming a fundamental skill. Particularly in high-tech industries, however, manuals are sometimes so large and complicated that they can no longer be effectively contained in book form, but are stored in specialised data bases on computers. Even in the case of less elaborate handbooks, this is a trend that is escalating.

Thus, during pilot work on this project, the production manager of a major pharmaceutical company in the South of England reported that in her company in 1990, at the shop-floor level between 30 - 40% of personnel would need to be able to follow technical instructions mediated via a computer (e.g. in stock control, warehouse management, and in handling equipment). In clerical, administrative and management positions, the figure rose to 70 - 100%, depending on the department. The likely continuation of this trend suggests that there will be fewer and fewer jobs available for people with poor technical literacy.

The crucial nature of the technical literacy problem is also emphasised by research into understanding of technical manuals. A vivid example was provided by Sticht (1977) who came to the conclusion that many operatives positively avoid using manuals because they find them difficult to understand, notwithstanding the fact that the reading might be profoundly important to safety or economy. In a study of U.S. Navy personnel, Sticht found that three-quarters of all reading occurring in the workplace was concerned with understanding instructions on how to perform a task, and 40% of these tasks were being performed for the first time.

Failure to understand or apply correctly the information contained in a manual can have extremely serious consequences. In civil industry it can result in loss of production, faulty goods and industrial injuries. In the military sphere it can lead to vulnerable defence systems. In certain circumstances, as has been highlighted by recent disasters in the transport industry, it may contribute to large scale loss of life.

The objective of the research reported in this paper was therefore to pilot and produce a computer-assisted technical literacy test, which would provide a valid method of identifying the level of a person's familiarity with or likely aptitude for work using a computer. It was intended that developing such a test would provide useful information in itself, but also that the test would subsequently be made available to schools and to industry. Funds for the Technical Literacy Project (TLP) were made available from the NatWest Bank Research fund, administered by Nottingham University, and work on the project was begun in August 1989.

Two crucial issues which had to be decided at the outset of the project were the nature of the test to be devised, and the selection of the population on which the test would be standardised. For reasons which will be more fully explained below, a 'hypertext' program (for a full review of hypertext studies, see Conklin, 1987) was chosen as the basis of the test, partly because it would be relatively unfamiliar to both school students and people in the workplace, but also because it could be made to simulate the type of task for which computers are likely to be used in industry in the future. It was decided to test two groups of subjects, school students in their final six months of compulsory schooling, and a cross-section of workers in industry.

## The Technical Literacy Project task

The nature of the tasks included in any test will naturally heavily determine the outcome when that test is administered. In the present case, the project team wished to devise a task, or related set of tasks, which examined subjects' ability to access information stored in the computer. This goal was consistent with the view that computers will be increasingly important in the workplace as entry points into complex information systems, whether these are technical manuals or other types of data base, and that in the coming years workers at all levels are likely to be called upon to use a computer for such a purpose. At the same time, keyboard skills are an important part of using most information systems, and the use of a 'mouse' for moving a cursor on a computer screen is also an increasingly common phenomenon.

For these reasons, the main part of the test which was developed was an ordering task for parts, such as might be used in a warehouse. The information about the parts to be ordered is stored in the form similar to that of a small technical data base, in that the subject can access extra information about the task itself and the parts to be ordered in both words and pictures. In order to complete the ordering task, however, the subject first has to work through a carefully graduated series of preliminary tasks, introducing them to skills which they will use later in the test. The preliminary tasks introduce the use of the mouse and the keyboard for making decisions and inputting data, so that novices with no prior experience of computers have an opportunity to progress through all stages of the test.

It was decided to program the test using the HyperCard system on a Macintosh computer. This was partly because the Macintosh machine would be unfamiliar to most potential subjects, since at the time of data collection its use was relatively rare in the UK, and there would be less chance of some subjects performing well simply because they were familiar with the machine on which the test was being conducted. The second reason for using the Macintosh was the HyperCard system itself.

HyperCard is a flexible multi-mode data base, which its creators, Apple Computer, call a 'unique information environment'. The program can store all kinds of information, including words, pictures, charts, and digitised photographs, and any piece of information can be connected to any other piece of information. Moving between pieces of information is simple: by pointing and clicking, using the mouse to guide the cursor on the screen, a person can navigate from one 'card' (or screen picture of information) to any other.

Such a system is ideal for introducing learners to new information, since it can be programmed to present tasks initially one at a time, as in a normal book, but then open up and become more flexible, appearing to the user more like an on-line, interactive data base.

The ordering task used in the TLP test was derived from early hypertext research by Stone and Hutson (1984). They studied the ability of subjects to carry out a simple task of building a Lego model using technical data stored in one of two ways, the first a normal book form, i.e. a technical manual with diagrams and glossary, and the second a computer-based hypertext form, containing the same information. Stone and Hutson's hypertext database included not only diagrams and text, but also additional data to assist the user, such as exploded diagrams which gave more detail, and a glossary to help users interpret any technical terms.

In the TLP task, a similar information environment is created, but with the subject's goal being to order parts rather than build the model, since an ordering task was felt to simulate a workplace task more effectively. In order to make the test more realistic and user-friendly, it was decided to create a two-part ordering task, with the subject first ordering parts for a real section of a Lego model which is presented to the subject, and which can be handled and examined closely; in part two, the subject has to order parts for a different section of the model, about which the only information available is that stored on the computer.

The programming for the TLP test was begun in August 1989, and initial test versions were piloted during November and December. The sequence of skills to be demonstrated in the final version was as follows:

(a) Use of a "mouse" for moving a cursor; pointing and clicking.
(b) Use of various types of on-screen "buttons", for navigating within the system.
(c) Computer keyboard skills.
(d) Combined use of button and keyboard skills.
(e) Combining the above skills to order the pieces of Lego necessary to build a section of a toy truck. This part of the test was divided into two:
(i) In the first part, the subjects had a Lego model in front of them, and various diagrams of the part were available, on-screen. From parts lists available on-screen in pictures, or in words, the correct items in correct numbers had to be selected and an order form completed and sent.
(ii) In the second part the exercise was repeated with another section of the Lego model, again with the help of a series of on-screen diagrams, but this time without the help of an actual model.

In deciding which subjects were to take the TLP test, a number of problems had to be addressed. First, while what employers wish to do is to identify aptitude for using a computer in the workplace, it must be accepted that this is very difficult to accomplish. One reason is that the predictive validity of aptitude tests may take a good deal of time to establish. Secondly, it is very difficult to partition out prior experience from aptitude: on a task involving computers, a subject who has a high degree of familiarity but low potential for learning may outperform a novice who has high potential but little or no prior knowledge of computers. Equally, it is very difficult to make useful general statements about the types of prior knowledge and experience of people in the workplace. In many cases, data about their education is difficult to collect or unreliable as an indicator of their current potential. Because of these factors, it was felt that there would be many problems in standardising the TLP test simply by administering it to workplace populations.

An alternative strategy, and the one which was adopted for this study, was to attempt to standardise the test on a carefully selected sample of pupils at the end of compulsory schooling. It was felt that employers would find it potentially valuable to be able to relate the performance of their employees on the TLP test to that of the average school leaver in 1990. This procedure might circumvent, at least to some extent, the problem of establishing validity, and would offer at least a partial basis of evidence on which to make training or selection decisions.

In order to broaden the sample, two comprehensive schools from the same large city were selected, both with wide catchment areas. One school drew upon a largely urban population in the north, and the other upon a largely suburban area in the south of the city. Both schools were co-educational, and every pupil in the final year of compulsory schooling in both schools was individually tested over a three-month period.

In order to gain information on performance on the test in the workplace, cooperation was obtained from three major industrial companies in the same city, and each agreed to make available a randomly-selected sample of between 50 and 100 workers, from all types of job, at all skill levels, from unskilled to top management. In this way it was hoped to obtain two sets of data on the basis of which reasonably reliable generalisations about performance could be made.

## Method

### Subjects

The subjects in the school population were 180 pupils (101 girls and 79 boys), mean age 15.5 years, who made up the entire population of those in the final year of compulsory schooling in their schools. The subjects in the industry group were a stratified random sample of 187 employees from three factories, (106 women and 81 men).

### Apparatus

A Macintosh Plus computer with mouse, keyboard and hard disk drive was used in the experiment. A specially written Hypercard program introduced the subject to the tasks, and stored data on the subject's activity. The program was activated by the experimenter positioning the cursor in a box on the screen display marked 'START', using the mouse, and clicking. The program then managed the task, concluding automatically after either the second order had been sent, or (more commonly) 25 minutes had elapsed.

### Procedure

Timing of the subject's activity on the task took place automatically, and the program recorded details of each card brought to the screen, and the length of time it was on the screen before it was replaced by another.

After some familiarisation exercises involving the mouse, the subject undertook two sub-tasks on which speed in using the mouse was recorded: in the first, the subject had to point and click on the numerals 1-9, which were randomly distributed in rectangles on the screen; the second was a similar task, but this time the goal was to click on the letters of the alphabet, in order. The time taken on these two tasks was recorded separately, and was taken as indicator of mouse-handling skill. Figure 1 shows what the subject sees on the screen at the start of the alphabet task.

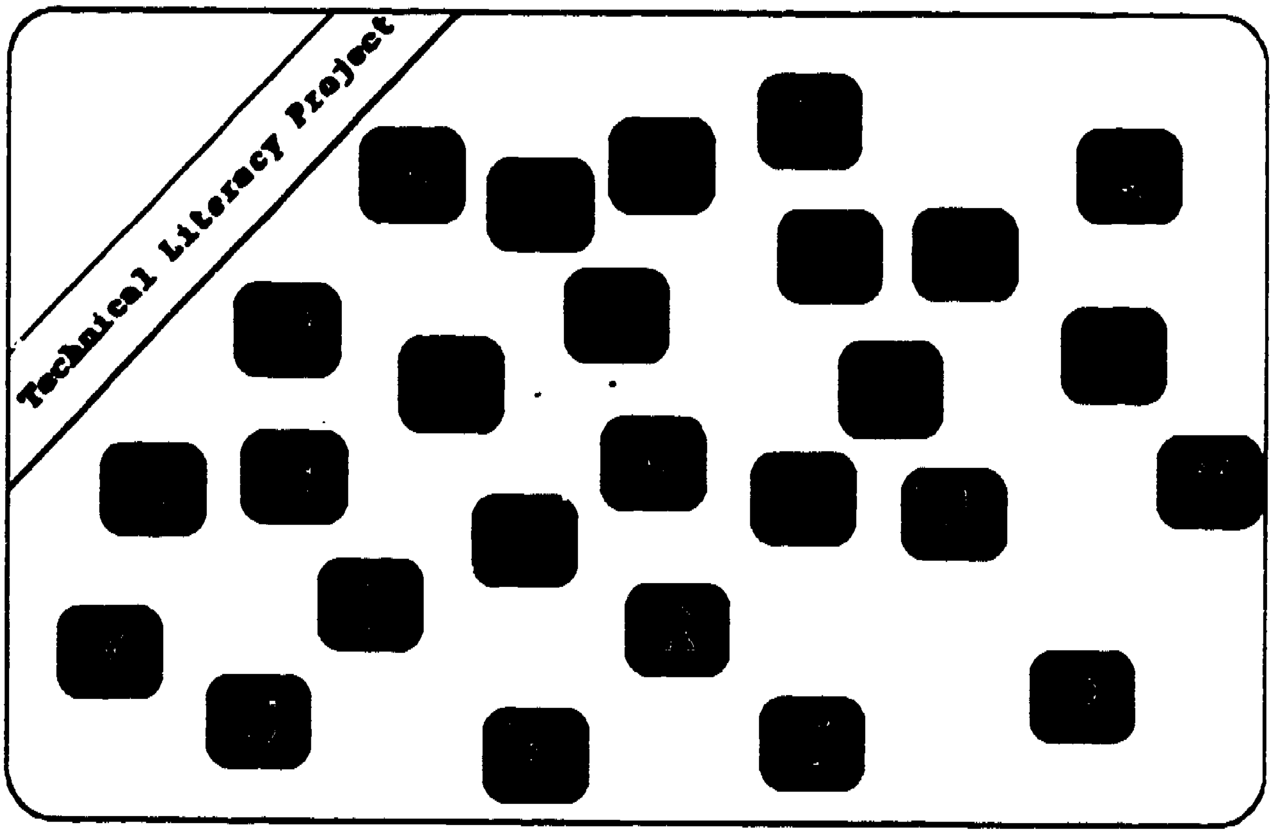


**Figure 1.** The Alphabet Task. The subject is required to point and click on the letters of the alphabet, in order.

Further instruction on the use of the keyboard and 'Return' key was followed by a request for the subject to type in details of his or her name, place of work or study, and age. The subject then went on to the task of ordering the Lego parts.

When the subject reached this point, the screen displayed a section of a Lego model. The section was one of two, randomly chosen, from the third stage of construction of a Lego Technic Model 8853. The finished model was of a type of tractor used in the building industry, but this could not be guessed from the sections used in the task, since these were internal sections of the main transmission assembly. Each section was made up of nine types of component. Between one and four examples of each of the nine components was needed in order to accurately complete that part of the model. The experimenter checked which section was on the display, and then handed the subject a tray on which was the section shown on the screen. The subject was permitted to examine, but not to dismantle, the section. Figure 2 gives an example of a typical screen display generated during the ordering task.

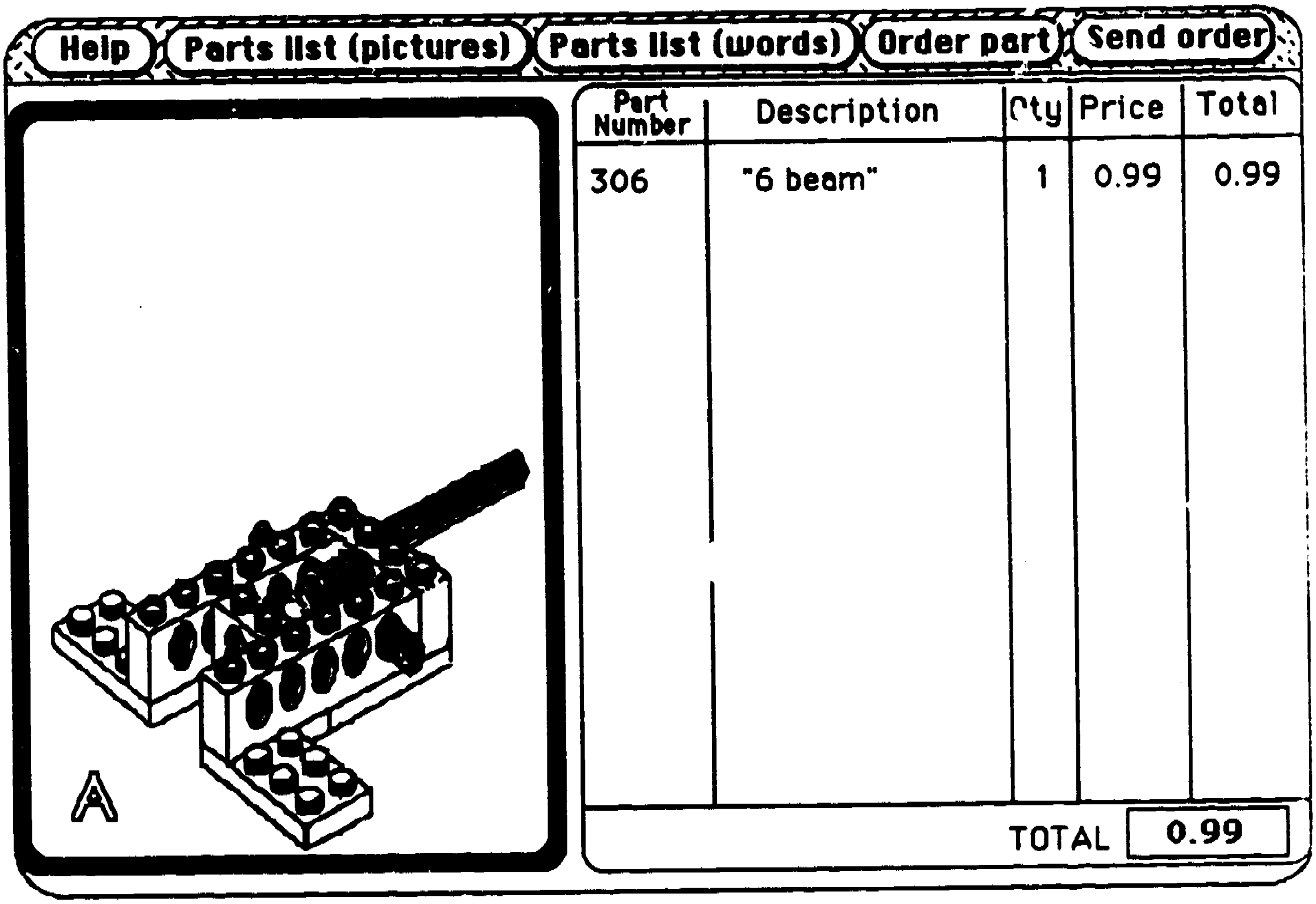


**Figure 2** An example of a typical screen display generated during the ordering task.

## Results

The main results of the subjects' performance are summarised in Table 1. As indicated earlier, the alphabet task time (AT) gives an indication of the subject's competence with the mouse, while the personal data entry time (PT) gives an indication of speed in entering information using the computer keyboard. For the Lego ordering tasks, two scores are presented: the number of components ordered correctly on Task A, the first task (A√), and the error score on the first task (Ax). The maximum score on A√ is nine, which is the number of different components in each section of the model used on the test, since a point is scored only when the subject has identified both the correct component and has ordered the exact number needed.

The error score, Ax, was included initially at the suggestion of a teacher in one of the participating schools, who argued that without this, some subjects might benefit unfairly from being able to order many incorrect parts without penalty. Such an error score, it was felt, would penalise the type of subject who pressed buttons indiscriminately, and assist a slower but more accurate subject. A subject's Ax score was increased by one for each component ordered in incorrect numbers. Since there were fifteen different components in all used in the two sections of Lego (i.e., there was partial overlap of components used) the maximum possible error score was 15. In the event, the greatest Ax score observed was 11, and this was found in both school and industry groups. Only 55 percent of subjects obtained a score on the second ordering task, Task B; this was because many ran short of time and failed to reach a point at which parts could be ordered. For this reason the results on Task B are not presented in Table 1.

Table 1. Technical Literacy Project mean scores. Significance levels on t values between gender groups within institution.

| Institution | Sex | n | AT sd | PT sd | A√ sd | Ax sd |
|---|---|---|---|---|---|---|
| School | Fem | 100 | 91.8 (37.0) | 116 (91.0) | 2.99 (3.67) | 3.36 (2.82) |
| | | | *** | n.s. | * | * |
| | Male | 80 | 72.3 (17.5) | 105 (63.8) | 4.84 (4.01) | 2.36 (2.64) |
| Industry | Fem | 105 | 88.7 (29.2) | 156 (141) | 2.81 (3.84) | 3.93 (2.75) |
| | | | * | n.s. | n.s. | ? |
| | Male | 83 | 81.6 (27.2) | 142 (95.9) | 3.41 (4.10) | 3.24 (2.77) |

Legend:
AT= Alphabet task time
PT= Personal data entry time
A√= Number of correct parts ordered on task A
Ax= Number of incorrect parts ordered on task A

In broad outline the results indicate that the greatest differences were within, rather than between, institutions. In both schools and industry, males outperformed females in their institution on all the tasks. They were quicker on both mouse and data-entry tasks, had higher scores on A√, the number of correctly ordered parts, and lower scores on Ax, the number of parts incorrectly ordered.

An notable within-institution difference was that of school students on the mouse task, on which boys were 21 per cent quicker than girls ($p<0.001$). Boys were also quicker on the data-entry task, though not significantly so, but they were significantly more successful than girls on the ordering task ($p<0.05$), and made fewer errors ($p<0.05$). In industry, the male subjects had a similar pattern of differentials, but these were not so striking, only reaching statistical significance in the case of AT, the mouse task.

A t-test was performed on the overall means between institutions, and the results of these comparisons are shown in Table 2. On each of the four scores, the means of the school students were better than those of the subjects who were work g in industry. On the mouse task, school students were quicker than the indu try group, but the difference was not statistically significant.

Table 2 Means, standard deviations and significance levels on t-test of comparisons between institutions on TLP test sub-tasks.

| Institution | n | AT (s.d.) | PT (s.d.) | A√ (s.d.) | Ax (s.d.) |
|---|---|---|---|---|---|
| School | 180 | 83.3 (28.3) | 111 (78.9) | 3.81 (3.8) | 2.92 (2.74) |
| Industry | 188 | 86.2 (28.3) | 151 (121.1) | 3.07 (4.0) | 3.79 (2.76) |
| Sig. of t | | N.S. | $p<0.001$ | $p<0.1$ | $p<0.05$ |

Legend:
AT= Alphabet task time
PT= Personal data entry time
A√= Number of correct parts ordered on Task A
Ax= Number of incorrect parts ordered on Task A

The most striking difference between the pooled scores for institutions was on the time taken for the personal data entry task (PT). The school students were much faster than workers in industry, and the standard deviations of the school students were smaller, too, which suggests that there was much greater variation in performance on this task among the industry group.

On the ordering task, between-group differences were present, but were not great. School students ordered more parts correctly, but variations in scores within institutions were so large that the differences were only on the borderline of statistical significance. The differences in the number of parts incorrectly ordered did achieve statistical significance, with the school students proving to be the more accurate.

A number of interaction effects were noted, in that the pattern of performance between the gender groups within the two institutions was found to differ significantly. Using a 2 x 2 within-subjects analysis of variance, a strong interaction effect was found on performance on the alphabet task (1, 356) $F= 18.71$, $p<0.0001$. No interaction was noted on the personal data-entry task, but there were significant interactions in both the ordering tasks, the number of correct parts ordered $(1, 358)$ $F = 8.80$, $p<0.0032$, and the number of incorrect orders $(1, 358)$ $F = 8.45$, $p<0.0039$.

## Discussion

The results section began with an account of differences within institutions, but it is important to emphasise that the between-institution differences were present and consistently in favour of the school students. This suggests that, if the sampling was adequate, school leavers are indeed acquiring computer skills, and that they are likely to be more immediately ready than people currently in employment to take on tasks in the workplace involving a computer.

However, some of the most important findings from the project's work concern not the generally better scores overall of the school students, but the relative performance of males and females in the two types of institution. In the industry population, while men were quicker and more accurate than women, the differences were not great, and only just reached statistical significance. Among school leavers, however, much greater differences in the performance of boys and girls were found. On the personal data entry task, these differences were not significant, but on the three other tasks, differences were significantly greater than was the case in industry. On the mouse task, AT, the girls were not only slower than the boys, they were slower than both males and females in industry. The significant interaction effects noted in the results section are also related to the fact that the differences between gender groups at school were greater than differences between the gender groups in industry.

At the inception of the project, there was no expectation that major differences between the performance of male and female school students on the test would be encountered. If anything, the expectation might have been that because of more extensive sex stereotyping and its consequent effects on employment, there would have been greater differences in the computer familiarity of male and female workers in industry than one would expect to encounter in school. Such an effect, however, might be a complex one to predict and quantify, since the computer has had a wide but uneven impact on different aspects of both traditionally male and traditionally female employment roles and activity.

In any event, the influence of educational technology upon schools since 1985 might have led one to predict that both boys and girls would have had similar opportunities to acquire at least some familiarity with computers, and that while differences in individual students' performance on the TLP task might be potentially great, such differences might not necessarily be strongly related to gender. Unfortunately, however, the present research seems to suggest that current educational (or parental) practice may be tending to increase the difference between the computer awareness of males and females. Such a view would be compatible with other work in the field. In their review of research into the use of computers by boys and by girls, Underwood and Underwood (1990) report findings which suggest that at school girls get less time on computers, get less expert help when they need it, tend to sit at the back or sides of the room, and ask fewer questions. At home, too, there is disparity, with six times as many boys as girls having a computer bought for them (Culley, 1988).

One could argue that in certain respects aspects of the TLP task discriminated against girls, since the alphabet task demanded spatial ability, on which girls are often reported to be poorer than boys (and it is the case that this sub-task was the one on which the greatest gender differences were noted), but again one should point out that this was the task on which female workers in industry performed better than the girls in school, so presumably the innate ability of females to do this type of task is not the central issue.

It is of course the case that the alphabet task required two types of knowledge- the ability to use a mouse, and knowledge of the order of the letters of the alphabet. No subjects were encountered in either population who did not know the order of the letters, but many subjects were impeded by their lack of familiarity with the mouse. This lack of familiarity certainly slowed the progress through the task of many subjects, and it may be that some of the scores on the ordering task were depressed as a result. However, the lower scores of female subjects on the ordering task cannot be fully explained by the argument that they spent longer on the alphabet task, since the female school students also had higher error scores than the boys; had the problem simply been a shortage of time, the correct order scores and the error scores would both have been low.

When preliminary results of the school students' testing were presented to teachers in one of the participating schools, a teacher of computing challenged the validity of the results, on the grounds that in his view they misrepresented the performance of girls. He did not accept that girls were poorer at using a computer than boys, and stressed that in his experience girls often had less prior knowledge, but were more methodical and careful than boys, and used their intelligence to solve problems and challenges that the boys would often fail to handle. In an attempt to investigate this claim, a further, exploratory, post-hoc analysis was undertaken, addressed at the incomplete data available on how subjects coped with Task B, the ordering task for which no tangible Lego material was available.

The results were illuminating, and are presented in Table 3. As was mentioned earlier, only 55 percent of subjects progressed far enough on this task to submit even a partial order, and the B√ and Bx scores therefore may be taken to represent the performance of subjects who already possessed a reasonable degree of computer awareness before taking the test. The results should be treated with caution, since they are based on a smaller sample, and show great variability, with standard deviations exceeding the mean for every group. Nevertheless, they suggest some interesting trends.

Table 3 Scores on the second ordering task (Task B), showing the number of subjects in each group who reached task B (n), means of number of parts correctly ordered (B√), and the error score (Bx).

| | | n | B√ | Bx |
|---|---|---|---|---|
| School | Male | 42 | 0.88 | 0.58 |
| | Female | 46 | 2.02 | 0.38 |
| | Overall | 88 | 1.45 | 0.48 |
| Industry | Male | 60 | 1.93 | 0.60 |
| | Female | 55 | 0.19 | 0.13 |
| | Overall | 115 | 1.42 | 0.36 |

First, the overall superiority of the school students over the industry group was maintained. The difference between the group means on the number of parts correctly ordered (B√) was small, and not statistically significant, but it does suggest that more school students were able to make slightly more headway on the task than the industry group. Perhaps the most striking finding was the significant interaction effect on the B√ score. A two-way analysis of variance indicated a very powerful interaction, with women in industry obtaining low scores, but girls in school gaining the highest scores of any group (1, 199) F= 7.95, p<0.01.

It is also important to consider the interrelationship between the number of parts ordered correctly and the number of incorrect orders. A high B√ score is less impressive if it is associated with a correspondingly high error score (Bx). The male industry subjects achieved a high B√ score, 1.93, but also had the highest error score, 0.60. This would suggest high computer familiarity (to reach this stage of the task), but poor accuracy in completing the order. By contrast, the female industry group had low scores on both B√ and Bx, which might suggest poor computer familiarity (few subjects reaching this stage of the task), but a relatively careful approach once it was reached. In the school group, the girls scored much more highly than the boys on the ordering task, but also had lower error scores. In both groups, the females' error scores were significantly lower than those of the male subjects. Indeed, the ratio of correct to incorrect orders made by the female subjects was more than twice that of the male subjects.

Here, then, is a possible explanation of the performance of different groups of female school students: overall, the project results clearly suggest that boys at the end of compulsory schooling have much greater computer familiarity than girls; however, among boys and girls who have computer familiarity, it may well be that girls work with more care and precision. Such an analysis is consistent with the data presented, but again it should be emphasised that since the data on Task B are only partial, the results are perhaps less reliable.

## Conclusions

The intention of the Technical Literacy Project was to devise and pilot a test of computer awareness which might be useful as a test of familiarity or aptitude. It was recognised from the outset that predicting aptitude is extremely difficult, and it was hoped that providing data on a number of facets of computer familiarity, together with some indication of the subject's alertness and skill in the more novel ordering task, would be potentially useful for selection and training in industry.

A reasonably detailed picture of the performance on the test of two very different groups of subjects was built up, thanks to the generosity of senior management in schools and industry, and the next stage in analysis will be to convert performance data to percentiles so that an individual's profile can be related to norms in both school and industry. An employer would thus be able to compare a subject's performance with that of an average school leaver or an average worker in industry, and obtain some indication of the degree of training a person would be likely to need to take on a computer-related role or task.

Clearly some of the gender-related differences highlighted by the data collected thus far give some cause for concern. The data presented here suggest that men and women in industry have much more similar levels of computer familiarity and awareness than is the case in schools, whereas in general boys at the end of compulsory schooling would appear to be much more computer-aware than girls. Nevertheless, the Technical Literacy Project data do not suggest that girls lack computer aptitude; there are indications that when they do have familiarity with computers, girls may make better use of the computer than boys.

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