An EPSS for lifelong learning in relation to psychological research methods

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Abstract: An electronic performance support system (EPSS) is a computer-based environment that can be used to augment and enhance an individual’s performance in a particular skill domain. In addition, an EPSS can facilitate skill and knowledge acquisition. Our ongoing research programme in this area has been investigating the potential utility of EPSS methods within a range of different domains. This current paper describes an application of the technique within the domain of quantitative research methods as taught within a psychology degree course. It outlines and discusses the results of an evaluative study of a prototype EPSS tool that has been created to facilitate the learning of psychological research methods.

Keywords: electronic performance support; EPSS; computer-based learning; human-computer interaction; statistics; statistical methods; quantitative research methods; web-based delivery; system evaluation.


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1 Introduction

Electronic performance support technology has become an important mechanism for facilitating skill and knowledge uptake and also enhancing an individual’s (or a group’s) performance in a particular domain (Barker, 1995; Gery, 1991; Bezanson, 2002). Many of the current approaches to using this technique grew out of the early pioneering work undertaken by Gery (1991). She applied EPSS techniques within business organisations; some important contributions within this area have also been made by Bezanson (2002). Naturally, the principles involved in using an EPSS can also be applied within other contexts such as education, continuing professional development and lifelong learning.

According to Barker (1995), from an educational perspective, an electronic performance support system (EPSS) is an online tool to facilitate knowledge and skill acquisition. Such tools can also enhance on-the-job performance (Gery, 1991; Bezanson, 2002). Another attractive feature of EPSS technology is its potential for supporting lifelong learning. In a previous paper (Barker and Hudson, 1998), we suggested that a fundamental requirement of an electronic performance support system is that it should increase a user’s on-the-job performance within a given task domain. This can be achieved in two basic ways. First, through the provision of automated aids; and, second, by providing various mechanisms to support on-the-job, just-in-time training – which will enable users of an EPSS-enabled system to learn as they do. Naturally, within an educational context, the emphasis on teaching and learning activities will change the underlying design emphasis that is employed. Therefore, we believe that an EPSS facility that is designed to fulfil an educational need should accommodate the following three basic requirements. First, it should act as a pedagogic agent to assess skill and knowledge requirements for a given task sequence and fill in the gaps relating to a user’s capability. Second, it must function as a transfer agent to develop skills and knowledge using on-demand and/or just-in-time mechanisms. Third, it should act as an augmentation aid to improve human performance – over and above an individual’s (or a group’s) innate natural ability.

The work described in this paper is based on the use of an integrated electronic performance support system for the facilitation of task execution within the domain of quantitative research methods (van Schaik et al., 2002). Our motivation for wanting to develop an EPSS for this domain stems from the current lack of availability of integrated systems for use in this area. Some approaches to the use of stand-alone, electronic teaching packages for specific techniques have been described in the literature – see, for example, Morris (2001). However, there is a growing need for more powerful integrated environments (Branford, 2001). Although online packages for supporting statistical tasks do exist (such as MINITAB and SPSS), these are not really regarded as integrated EPSS systems. Such an integrated environment should explicitly support the various tasks that a student or researcher encounters when conducting a research project.

Although our system has been designed primarily for use by students following psychology courses, the system can also be used within other domains – both undergraduate and postgraduate. For example, students following courses in human-computer interaction (HCI) often have to design experiments to observe human behaviour (such as reading rates, typing speeds, reaction times, and so on). Students who study HCI therefore need to know how to design and conduct experiments. They also need to understand which statistical tests that they should use in order to analyse their
data and make inferences based upon their observations. The EPSS environment described in this paper is designed to meet this need.

In the remainder of this paper, we briefly describe the implementation of the prototype performance support system that we have built. We then give details of the evaluative study that we have conducted with respect to undergraduate usage and opinions of the system.

2 System design and development

This section of the paper briefly discusses the various phases involved in the design and development of the EPSS facility. As has been discussed elsewhere (Bezanson, 2002; van Schaik et al., 2002), there are a number of different architectures available for building an EPSS. For the work described in this paper, a component architecture rationale was employed – each system component being able to access an underlying system-wide database facility. A more detailed description of the design and development work is given in Barker et al. (2003).

2.1 The needs analysis

In order to identify relevant content for the EPSS, a needs analysis was conducted. This took the form of a survey of psychology students at the University of Teesside. The needs analysis was undertaken in order to identify the most important topics (relevant to quantitative research methods and statistics) that the EPSS should contain. It also served to determine whether students would be likely to use an EPSS to support their studies. The results of the needs analysis were also used to identify the nature of the materials and learning aids that the students currently employ. It was found that the main statistical software used by the students was the *Statistical Package for the Social Scientists* (SPSS).

2.2 Design and development

The prototype EPSS facility was designed to fulfil the requirements identified in the needs analysis (described above). From this analysis, it was concluded that the system had to provide four basic types of tool: a help system; an advisor system; a personal area and notes facility for each user; and an appropriate selection of performance aids. Each of these building blocks is briefly discussed below. The EPSS was developed as a stand-alone system because – although it supported task performance using SPSS – the system was intended to support the application of statistical analysis more widely.

The help system. The aim of the Help facility was to allow users to obtain easy access to any available information relating to quantitative research methods and statistical concepts that happened to be stored within the Help table within the underlying system database. When constructing the help facility, the needs analysis was used to highlight potential areas in which users might need support. The analysis results were therefore used to identify the content areas that the help system should attempt to cover. The Help system and the other sub-systems were available as separate options from the main system page.
The advisor system. The aim of this tool was to guide users towards information about procedures that they wanted to carry out or towards concepts that they wished to learn about. When the system guides users towards appropriate information, they are given a number of optional choices at each level of the hierarchical decision tree that is used to navigate through the EPSS content pages. As users proceed through the navigation tree for any given topic, each of these options is explained. Each leaf in the navigation tree states a statistical procedure that should be carried out – given choices made at previous nodes in the tree – and how this can be done using SPSS. The domain knowledge of the EPSS was organised into two broad areas that dealt with descriptive statistics and inferential statistics, respectively. These correspond with two main types of statistical analysis that are frequently conducted in psychological research and other such studies.

The personal area and notes. The aim of the personal area and personal notes was to allow the incorporation of personal performance aids and tools. In order to access their personal area and their personal sticky notes (annotations), users must log into the system. Once logged in, users are able to add, edit and remove their notes from the host pages that they relate to. When within their individual personal areas, users are also able to add links to personal performance aids and tools on the Internet as well as edit and remove all of the sticky notes that they have added to pages.

The performance aids. The performance aids that were developed were intended to provide special purpose tools to execute tasks that students would normally carry out by hand. For example, within the prototype EPSS, one of the generic skill areas that has been implemented involves power analysis table look-up. The EPSS is able to cater for two possible situations. First, it could be used for within subjects tests (using the related t and Wilcoxon’s T standard statistical tests). Second, it could be applied to between subjects tests (based on the use of the unrelated t and the Mann-Whitney U statistical procedures). Each of these could be applied in both a prospective and a retrospective way. In a prospective analysis, the required sample size was calculated for a particular effect size, significance level and power. In a retrospective analysis, power was calculated for a particular sample size, effect size and significance level.

3 Evaluation

3.1 Method

An evaluation of the prototype EPSS for quantitative research methods was conducted in order to establish students’ performance with the system and their overall acceptance of it as a teaching and learning aid. In addition, students’ level of knowledge of concepts in quantitative research methods was also analysed to allow for some form of assessment of the benefits of the EPSS compared to unaided performance.

3.2 Design and participants

The EPSS was evaluated as part of revision lab classes (class sizes of 15–20) at the start of the second academic year of an undergraduate Psychology programme. The evaluation employed a single sample of 89 Psychology students (75 females, 13 males and 1 not stated) who had taken two research modules in their first year of study; the quantitative
research methods’ content of these modules was included in the EPSS. The students’ mean age was 24.6 with a standard deviation of 8.4. Students rated themselves as possessing relatively little experience with regard to quantitative research methods (median = 2.5 with semi-interquartile range (siqr) = 0.9 on a 5-point Likert scale) and SPSS (median = 2 with siqr = 0.9 on a 5-point Likert scale). They rated themselves as moderately experienced in the use of computers (median = 3 with siqr = 0.5 on a 5-point Likert scale).

3.3 Materials and apparatus

The EPSS was mounted on an intranet server. A questionnaire was used as an evaluation instrument and was divided into four sections. The first section measured students’ prior knowledge of concepts in quantitative research methods; it employed 20 multiple-choice questions. The answer sheet required respondents to write down as their answer:

- one of four answer alternatives presented for each question
- their level of confidence (percentage) in the answer given.

Section 2 measured the demographic details of respondents. The third section of the questionnaire measured the students’ task performance when using the EPSS – through the answers that they gave in response to tasks they were asked to conduct. Finally, Section 4 was used to measure the respondents’ acceptance of the system, including the key concepts of perceived usefulness and intention to use – as identified in technology acceptance research (Davis and Venkatesh, 1996). Five-point Likert scale items were used in Sections 2 and 4 of the questionnaire.

3.4 Procedure

Students first filled in Section 1 of the questionnaire. Next, they were instructed to use and explore the EPSS for ten minutes. Following this, they were asked to answer the questions in Sections 2–4 and use the EPSS as needed when completing Section 3.

4 Results

4.1 Knowledge of concepts in quantitative research methods

For the 20 knowledge questions, the mean percentage of correct answers was 53.1 with a standard deviation of 12.2. The mean confidence in answers was 48.2% with a standard deviation of 18.3. The percentages of correct answers for individual questions are presented in Table 1 (for examples of questions see Appendix 1). As can be seen from this table, six concepts had fewer than 40% of correct answers. For all the 20 questions, the percentage of correct answers had a significant correlation with confidence, \( r = 0.25, p < 0.05 \).
Table 1 Percentages of answers to knowledge questions

<table>
<thead>
<tr>
<th>Q</th>
<th>Concept</th>
<th>Percentage correct</th>
<th>Confidence – mean (sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Central tendency</td>
<td>99</td>
<td>78 (25)</td>
</tr>
<tr>
<td>2</td>
<td>Variability</td>
<td>21</td>
<td>48 (23)</td>
</tr>
<tr>
<td>3</td>
<td>Normal distribution</td>
<td>65</td>
<td>49 (25)</td>
</tr>
<tr>
<td>4</td>
<td>Bi-variate correlation</td>
<td>32</td>
<td>34 (21)</td>
</tr>
<tr>
<td>5</td>
<td>Significance testing with two groups</td>
<td>61</td>
<td>53 (27)</td>
</tr>
<tr>
<td>6</td>
<td>Descriptive statistics</td>
<td>63</td>
<td>47 (26)</td>
</tr>
<tr>
<td>7</td>
<td>Parametric test for two unrelated samples</td>
<td>57</td>
<td>45 (28)</td>
</tr>
<tr>
<td>8</td>
<td>Level of measurement</td>
<td>63</td>
<td>43 (28)</td>
</tr>
<tr>
<td>9</td>
<td>Validity</td>
<td>81</td>
<td>60 (27)</td>
</tr>
<tr>
<td>10</td>
<td>Correlation</td>
<td>74</td>
<td>45 (31)</td>
</tr>
<tr>
<td>11</td>
<td>Sampling</td>
<td>76</td>
<td>67 (24)</td>
</tr>
<tr>
<td>12</td>
<td>Causation</td>
<td>78</td>
<td>58 (25)</td>
</tr>
<tr>
<td>13</td>
<td>Errors in statistical testing</td>
<td>17</td>
<td>43 (28)</td>
</tr>
<tr>
<td>14</td>
<td>Degrees of freedom</td>
<td>39</td>
<td>37 (25)</td>
</tr>
<tr>
<td>15</td>
<td>Parametric test for two related samples</td>
<td>62</td>
<td>41 (25)</td>
</tr>
<tr>
<td>16</td>
<td>Design when using two related samples</td>
<td>84</td>
<td>56 (29)</td>
</tr>
<tr>
<td>17</td>
<td>Linear regression</td>
<td>2</td>
<td>37 (26)</td>
</tr>
<tr>
<td>18</td>
<td>Graphical representation of interval level data</td>
<td>83</td>
<td>48 (29)</td>
</tr>
<tr>
<td>19</td>
<td>Binomial distribution</td>
<td>18</td>
<td>38 (26)</td>
</tr>
<tr>
<td>20</td>
<td>Homogeneity of variance</td>
<td>52</td>
<td>37 (29)</td>
</tr>
</tbody>
</table>

Q = question; sd = standard deviation.

4.2 Use of the EPSS

The percentages of correct answers for the four questions requiring the use of the Advisor system showed good performance on three questions (see Table 2) (for examples of questions see Appendix 2). An overall score for EPSS performance was calculated as the total number of correctly answered questions and items found in the Help system. The mean percentage score was 84.6 with a standard deviation of 13.9.
Table 2  Percentages of answers to questions requiring use of the EPSS

<table>
<thead>
<tr>
<th>EPSS sub-system</th>
<th>Question topic</th>
<th>Percentage correct or found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advisor</td>
<td>Measure of central tendency for parametric data</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Parametric test of independent measures design</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>SPSS menu selections for parametric test of independent measures design</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Test for relationship in ordinal data</td>
<td>47</td>
</tr>
<tr>
<td>Tools</td>
<td>Prospective power analysis</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Retrospective power analysis</td>
<td>90</td>
</tr>
<tr>
<td>Help</td>
<td>Mode</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Interpolation</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Effect size</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>t-test</td>
<td>79</td>
</tr>
</tbody>
</table>

4.3 System acceptance

The usefulness of the EPSS for learning, revision and completing assignments each had a very high median score (5 on a five-point scale). The perceived likelihood of using the EPSS, if it was made available through the university’s intranet, also had a median score of 5. Using Kendall’s tau, it was established that all four system-acceptance questions were significantly correlated.

5 Discussion

Overall students’ performance using the EPSS was high (mean = 84.6% correct). This indicates that the EPSS was successful in supporting students when performing tasks related to quantitative research methods. Although outcome measures of knowledge and EPSS use were not designed for a direct comparison, overall students’ performance using the EPSS was higher than unaided performance on knowledge questions (mean = 53.1% correct). These results show a 31.5% improvement when making use of the EPSS. Comparing students’ level of knowledge and their success on tasks with the EPSS more specifically, it was found that in the area of parametric test for independent measures design (knowledge question 7 and Advisor question 2), students’ performance specifically improved by 33%. These results suggest that the EPSS can be used as a means to improve students’ performance.

Overall, knowledge levels indicated that there was scope for improving students’ performance. Specific areas of poorer performance were variability, bi-variate correlation, errors in statistical testing, degrees of freedom, linear regression and binomial distribution. Further development of the EPSS could address these areas in more detail within the Advisor system and Help facility.
There was a non-significant correlation between students’ performance in terms of
• knowledge of concepts
• success in using the EPSS.

This correlation together with the non-significant difference in aided performance
between the better and poorer students in terms of unaided performance indicates that
students with different levels of knowledge benefit equally from using the EPSS for
revision.

The correlation between performance and confidence when using the EPSS was not
examined in this study. However, the significant correlation between confidence and
performance on the knowledge questions indicates that use of the EPSS may not only
result in increased student performance but might also produce an increase in confidence
as well.

Regarding perceived usefulness, students expected that the EPSS would be useful to
them for learning, revision and completing assignments. Relating intention to use,
students believed that it was likely that they would use the system if it was made
available to them through the university’s intranet. The significant correlations between
acceptance measures confirmed the association between intention to use and perceived
usefulness found in previous research (Davis and Venkatesh, 1996).

The relevance of our EPSS facility in the context or lifelong learning arises from two
important observations. First, many people emerging from higher educational systems are
often ill-equipped to use and understand the importance of statistical methods within all
branches of engineering and science. Second, new statistical techniques are continually
emerging; it is therefore important that people keep up-to-date with new developments.
A full implementation of our electronic performance support system would enable each
of these shortcomings in our educational systems to be addressed through the use of
lifelong learning.

6 Conclusions and future work

The EPSS that we have developed has extended the range of electronically supported
domains to the area of quantitative research methods using a web-based implementation.
This implementation makes it possible to support a global user community of learners
and researchers with regularly updated support. For this reason, the EPSS facility offers a
powerful environment for the support of lifelong learning. The global scope of our
system is in line with developments towards global educational and training systems such
as virtual universities (Hazemi and Hailes, 2001). Further details of our ongoing work in
this area are given elsewhere (Moukadem et al., 2002).

The evaluation results of the EPSS in the context of revision are encouraging.
However, the value of the EPSS should also be assessed in other situations such as
learning and completing assignments (especially by measuring on-the-job performance
metrics such as reduction in errors per unit time, more rapid completion of tasks,
and so on) – as well as in the context of lifelong learning and continuing professional
development.
The scope of the EPSS could be extended in various ways in order to make it more widely applicable. In particular, the range of the quantitative research methods included in the system could be increased. Furthermore, the scope of the domain could also be extended in order to make it more general. This could be achieved by supporting the process of research from start to finish rather than just considering the research methods’ aspect. Although various textbooks describing or prescribing the overall research process are available – see, for example, Robson (1993) – online support in the form of an EPSS is still lacking.

The functionality of the EPSS could be extended in order to support a wider range of tasks within a learning or research context. For example support for communication between users could be provided. This could be implemented by linking the EPSS with existing tools for electronic communication – such as electronic mail and/or a computer conferencing facility. Furthermore, the set of tools provided by the EPSS and the number of links to other (online and offline) resources could be expanded in order to facilitate the creation of a multimedia knowledge web.

Finally, further research would be valuable in exploring how this, or a related EPSS, could be integrated with the SPSS application and other related applications. With the current, stand-alone EPSS model, one has the advantage of using relatively inexpensive implementation, and the disadvantage of requiring SPSS users to interrupt their work and access a separate application – the EPSS. With a linked EPSS, doing and learning can be seamlessly integrated in a context-sensitive environment. We can take this argument even further: an especially rich area for research would be to influence and assist the manufacturer of SPSS to evolve that application with performance-centred design methods to the point that the application has intrinsic user-support built into its design. This would greatly reduce the need for external resources such as described in the present EPSS. In such a model, users could learn while doing, including lifelong learning while lifelong doing, coached along on their jobs by the application itself, not by a separate EPSS.

Acknowledgements

A previous, more detailed version of this paper has been published in the CBLIS 2003 conference proceedings (Barker et al., 2003). The authors are grateful to the referees for the useful suggestions that they made for improving the paper.

References


Appendix 1: Examples of knowledge questions

The arithmetic average is also known as the
a) mean
b) median
c) mode
d) central tendency.

As the difference between the means of two groups grows larger, the likelihood that their difference is statistically significant
a) decreases
b) increases
c) remains the same
d) is due to error.
The appropriate test of statistical difference between two samples of interval level data gathered from two different sets of people would be
a) the chi-square test
b) Spearman’s rho
c) independent samples’ t-test
d) Mann-Whitney U test.

Lowering the significance level from 5% to 1%

a) decreases the probability of making a Type II error
b) decreases the probability of making a Type I error
c) means we are using a one-tailed test rather than a two-tailed test
d) increases the power of the statistical test.

A correlation of zero means that
a) two variables are totally unrelated
b) as the first variable increases the other decreases
c) as the first variable decreases the other increases
d) participants tended to score around zero on both variables.

Appendix 2: Examples of questions requiring use of the EPSS

- what measure of central tendency should be used for normally distributed interval level data?
- what statistical test should be used if you carried out an experiment where every participant took part in both levels of the independent variable, the data were of interval type and were normally distributed, and you were looking for differences?
- what procedure would you carry out if you wished to study ordinal level data to see if there was a relationship between two variables?
- calculate the number of participants required for a prospective power analysis where the effect size (d) = 0.3, power = 0.8, for a two-tailed hypothesis for a related t-test
- calculate the power of a retrospective power analysis where the effect size (d) = 0.56, n = 78, for a one-tailed hypothesis for a Mann-Whitney U test.