The effect of questioning on concept learning within a hypertext system

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Abstract Two studies report upon the effect of asking learners to answer questions when learning in a hypertext environment, even when no immediate feedback is given to learners about the appropriateness of their responses. Such questions may be useful as a means to induce responses that can be used to monitor learning, but here the hypothesis was investigated that their inclusion would also improve learning directly. In the first study, 80 student teachers answered embedded multiple-choice questions that encouraged analysis of examples. Concept learning achieved using this environment was significantly reduced when compared with an environment requiring no such responses. In the second study, a cohort of 68 students were asked to summarise the information illustrated by the examples. Here, learning was significantly improved as compared with the no-response condition.

Keywords: Constructivist; Hypermedia; Mediated; Problem solving; Qualitative; Questionnaire; Teachers; Training

Introduction

Open and flexible learning programmes are increasingly being facilitated by email conferencing which often links to online hypertext resources. However, the efficiency and cost-effectiveness of such an approach in isolation is debatable (Wilson & Whitelock, 1998; Trentin 2000). An alternative to email dialogue for online monitoring of students’ learning may be to further exploit the ability of hypertext to facilitate communication from the student to the tutor. Questions embedded in hypertext can efficiently elicit responses from learners which are conveniently constrained and which can be more easily monitored than the types of wordy responses often associated with email conferencing. Such responses can help track the progress of the student and at least form part (although it is not suggested all) of the feedback loop described by Keegan (1990) that supports the quality of course delivery.

Apart from helping to track the student’s progress, the insertion of questions may also improve learning more directly. In studies involving conventional text, it has been shown such questions may encourage backward processing and involve the reader in organising and repeating previous prose content or, through forward processing, optimise mathemagenic behaviours on passages following the questions.
It would appear that higher-order questions, such as comprehension and analysis, support the learning of concepts more effectively than lower-order questions (Andre, 1979; Hamilton, 1985) and also demand greater attention from the learner (Halpain et al., 1985). Felker & Dapra (1975) and Watts & Anderson (1971) found that students’ problem-solving abilities could be improved if the text that set out the principles was punctuated by questions requiring their application to novel examples. Possibly, this improvement is achieved by inducing the learner to consider the given concepts within new settings (Tennyson & Parks, 1980). It has also been shown that embedded questions involving novel examples help students identify more clearly their level of understanding (Glenberg et al., 1987), thus encouraging more selective and efficient revision of the text (Walczyk & Hall, 1989).

There is also evidence that questions which require the student to generate their own information can support the retention of that information (Greene, 1988; Gardiner, 1989). Such generation effects may be evident in techniques such as concept mapping — which engages the reader in efforts to assemble an overview of the information provided. The technique of concept mapping has been used successfully to improve learner’s acquisition of factual and relational knowledge in hypertext learning environments (Reader & Hammond, 1994). Such generative techniques are allied to constructivist educational philosophy and encourage an active, constructive, cumulative and goal-directed process (Shuell, 1988).

This investigation reports upon two different approaches to questioning within a hypertext environment and their consequent effect upon learning.

**Study 1**

**Sample**
The study involved 80 female student teachers in the first year of a programme training them to teach young children.

**Topics and learning environments**
Learning environments were designed to support learning in two ‘Technology’ topic areas relevant to the primary school classroom:

- cutting processes;
- joining processes.

Traditionally (e.g. Blythe et al. 1996) decisions about cutting and joining materials are achieved by first analysing the situation and the properties of the material(s) involved, and then selecting the appropriate process (see Fig. 1).

![Fig. 1. Solving problems of cutting and joining different materials.](image)

It was intended that by the end of their online learning experience, students would be able demonstrate the acquisition of conceptual knowledge by indicating how to cut and join new materials in novel situations. The hypertext learning environments for each topic consisted of the presentation of 5 general rules and 10 examples (each
A typical prescribed joining rule was: ‘If both materials are nonabsorbent, nonfibrous but flat, then use double-sided sticky tape for an instant join’. The 10 examples each consisted of a description of the situation with a picture of the material(s) involved, an analysis of the situation and material(s), and the solution showing a picture of the appropriate tool or process identified with a caption (see Fig. 2(a)).

2a) an example of a situation and materials.

Example: How can you instantly join 2 flat pieces of thin plastic sheet (face to face)?
Analysis: Both materials are flat, non-absorbent and non-fibrous. You need to make an instant join.
Solution: So ….. use double-sided sticky tape

2b) the MCQ questionnaire intended to encourage analysis of the situation and the choosing of the correct rule and process.

Tick the statements that are true:
The materials I am joining are:
- [ ] Flat
- [ ] Both non-absorbent
- [ ] Both non-fibrous

I want to:
- [ ] Join edges
- [ ] Make an instant join

Fig. 2. Illustrative extracts from learning materials for the topic ‘Joining Processes’

The first study included a questioning activity which would encourage a higher-order activity such as analysis (Bloom, 1956). To investigate the effects of such questioning, two environments were prepared. The ‘no response’ learning environment (N) consisted of a simple linear presentation of the rules and examples with an analysis and solution of each example provided directly underneath it. The A_MCQ learning environment required the students to respond to a Multiple Choice Question (MCQ) questionnaire that demanded that they analyse, in turn, each of the 10 examples before they were allowed to see each solution. The solution was provided on a separate screen that appeared when their simple MCQ analysis of the example was submitted. This analysis consisted of 5 true/false statements (see Fig. 2(b)), any number of which could be indicated by the student as true by clicking in the box next to the statement. It was hoped that this analysis would serve as a discriminative stimulus that would cue certain processing behaviours (Rickards, 1979) — in this case the linking of the properties of the materials and the circumstances of the situation to the solution described subsequently.

A summary describing the learning environments evaluated in Study 1 and Study 2 is provided in Table 1.
Procedure
A balanced within-subjects experimental design was followed in which all subjects experienced both learning environments. Treatments, topics and order of presentation were permuted to balance practise effects and effects due to differences in topics, giving rise to 4 conditions in total. 80 undergraduate students took part, with 20 randomly assigned to each of the 4 conditions.

Table 1. Summary of the 3 types of learning environment studied in this investigation. The first study compared A_MCQ with N, the second study compared R_GEN with N.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>5 rules indicating a prescribed analysis to be undertaken and how this leads directly to a solution (i.e. appropriate choice of process)</td>
</tr>
<tr>
<td></td>
<td>followed by 10 examples of illustrative situations (2 per rule), each accompanied by an appropriate analysis and solution.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Analysis using Multiple Choice Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_MCQ</td>
<td>5 rules indicating a prescribed analysis to be undertaken and how this leads directly to a solution (i.e. appropriate choice of process)</td>
</tr>
<tr>
<td></td>
<td>followed by 10 examples of illustrative situations (2 per rule), each on 2 screens:</td>
</tr>
<tr>
<td></td>
<td>Screen 1: example &amp; MCQ questionnaire requiring students to carry out own analysis and thereby help them choose the correct rule. On submission of this analysis, Screen 2 appears.</td>
</tr>
<tr>
<td></td>
<td>Screen 2: solution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Rule Generation by students</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_GEN</td>
<td>10 examples of illustrative situations (2 per rule), each accompanied by an appropriate analysis and solution.</td>
</tr>
<tr>
<td></td>
<td>followed by A text box in which students are requested to enter their own 5 rules.</td>
</tr>
</tbody>
</table>

Students first undertook a self-assessment of their own computer skills, to determine their general confidence with computers. Students were asked to express their confidence by writing a score from 0 to 5 against a set of 40 skills, where 0 = complete beginner and 5 = fully confident. These statements appeared under the 5 headings of general computer skills, word-processing, data handling, presentation/graphics and information services. Scores under all sections were combined to give a general summary of the student’s computer confidence as a single number.

Prior to accessing the learning environments, students carried out an online pre-test of their knowledge of both topics, and an online post-test was carried out immediately afterwards. Using multiple-choice format, these tests were of a problem-solving type and students were asked to select appropriate cutting and joining processes, scoring a maximum of 20 marks for a complete set of correct responses. The materials and situations described in the post-test were novel (i.e. not specifically considered previously) but full marks could be achieved by correctly applying the 5 general rules provided.

The students were allowed to pursue their learning at anytime during a fixed two week period. They could access the learning environments at home (via telephone modems) or at college — which would provide faster access. Students were required to enter start and finish times to indicate how long they studied each topic for. It was emphasised that no results arising from the study would be used to formally assess them and all outcomes would remain confidential, although they might be considered
privately by their lecturer when planning group-based revision sessions.

After the 2-week period, students were asked to fill in a questionnaire in which they were asked, retrospectively, to indicate their general prior anxiety about the online learning experience on a scale of 1–10. They were also asked to identify the worst difficulty and best advantage of this type of online learning experience and to suggest the percentage of their normal ‘live’ lectures they would like to have replaced with such an approach.

Results for Study 1

For each learning environment (N and A_MCQ), the learning achieved by each student was calculated as the increase in the score achieved in the post-test relative to the pre-test. Pre-test, post-test and learning scores achieved using each type of environment are summarised in Table 2, together with the duration spent working with each.

Table 2 Scores and the learning achieved in the first study.

<table>
<thead>
<tr>
<th></th>
<th>Pre-test scores</th>
<th>Post-test score</th>
<th>Learning</th>
<th>Time spent studying (mins.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td><strong>m</strong></td>
<td><strong>sd</strong></td>
<td><strong>m</strong></td>
<td><strong>sd</strong></td>
</tr>
<tr>
<td>Pre-test</td>
<td>8.29</td>
<td>3.08</td>
<td>12.22</td>
<td>2.41</td>
</tr>
<tr>
<td>Post-test</td>
<td>12.22</td>
<td>2.41</td>
<td>11.16</td>
<td>2.91</td>
</tr>
<tr>
<td>Learning</td>
<td>3.93</td>
<td>3.40</td>
<td>2.86</td>
<td>3.95</td>
</tr>
<tr>
<td>Time spent</td>
<td>10.01</td>
<td>5.49</td>
<td>13.44</td>
<td>6.81</td>
</tr>
</tbody>
</table>

The learning gain was calculated as the difference between pre- and post-test scores. A simple paired-samples *t*-test was carried out, revealing a significant decrease in learning when students were learning using the A_MCQ environment, compared with the N environment that required no response (*t* = 2.07, *p* = 0.042). This was despite the greater average time spent working with the A_MCQ environment.

Correlation coefficients (Pearson’s *r*) were calculated between the following variables: Pre-test score (totalled over both topic areas), computer confidence, prior anxiety, and learning for both environments. Table 3 shows the correlation coefficients obtained. Scatter plots confirmed significant correlations.

Table 3 Correlation coefficients (Pearson’s *r*) for the first study

<table>
<thead>
<tr>
<th></th>
<th>Pre-test total</th>
<th>Computer confidence</th>
<th>Prior anxiety</th>
<th>Learning N</th>
<th>Learning A_MCQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test total</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer confidence</td>
<td>– 0.08</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior anxiety</td>
<td>– 0.13</td>
<td>– 0.34**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning (N)</td>
<td>– 0.46**</td>
<td>– 0.05</td>
<td>0.01</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Learning (A_MCQ)</td>
<td>– 0.44**</td>
<td>0.07</td>
<td>– 0.05</td>
<td>0.08</td>
<td>1.00</td>
</tr>
</tbody>
</table>

** *p* < 0.01

A high negative correlation between computer confidence and anxiety (*r* = – 0.34, *p* = 0.003) would indicate that much of this concern was associated with lack of computer experience. A significant negative correlation was identified between original knowledge (as measured by summing pre-test scores over the two topic areas) and learning using both the N and A_MCQ environments (*r* = – 0.46, *p* < 0.001 and *r* = – 0.44, *p* < 0.001, respectively), demonstrating that those who knew less to begin with appeared to benefit more.
Study 2

The disappointing results from the first study caused a re-evaluation of the task that the students were being given. In the second study, it was decided that learners should be asked to generate their own rules, thus exploiting the generation effect. The method followed for the second study was identical to the first, except for the following changes. A new Rule-Generating (R_GEN) learning environment was devised that did not include the prescribed rules, but displayed the examples (as in the N environment) with a single question asking the student for 5 rules which would account for the 10 examples shown (see Table 1). The ‘no response’ N-treated environment (with the 5 rules and 10 examples) was used, as previously, as the control condition. Secondly, due to fluctuations in teacher recruitment, a slightly smaller group of 68 female students participated, giving 4 groups of 17 each. Finally, as an improvement upon the methodology used in the previous study, students were asked to give anxiety ratings prior to the study commencing rather than retrospectively, and they were also asked to indicate, after having participated, where they had accessed the materials (i.e. at home or at college).

Results for Study 2

Pre-test, post-test and learning scores achieved using the two environments are summarised in Table 4, together with the duration spent working with each environment.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th></th>
<th>R_GEN</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>sd</td>
<td>m</td>
<td>sd</td>
</tr>
<tr>
<td>Pre-test scores</td>
<td>6.75</td>
<td>3.16</td>
<td>6.34</td>
<td>2.93</td>
</tr>
<tr>
<td>Post-test score</td>
<td>9.32</td>
<td>2.85</td>
<td>9.90</td>
<td>2.93</td>
</tr>
<tr>
<td>Learning</td>
<td>2.57</td>
<td>2.83</td>
<td>3.56</td>
<td>2.19</td>
</tr>
<tr>
<td>Time Spent Studying (mins)</td>
<td>11.11</td>
<td>2.72</td>
<td>17.43</td>
<td>7.87</td>
</tr>
</tbody>
</table>

A simple paired-samples $t$-test was carried out, this time revealing a significant increase in learning when students were using R_GEN environment, compared with the N environment that required no response ($t = 2.20, p = 0.031$). Students appeared to spend longer within the R_GEN environment than with either the N or A_MCQ environments.

Associations between variables were identified as before, and the results of this analysis are shown in Table 5.

<table>
<thead>
<tr>
<th></th>
<th>Pre-test total</th>
<th>Computer confidence</th>
<th>Prior learning</th>
<th>Learning N</th>
<th>Learning R_GEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test total</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer confidence</td>
<td>0.16</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior anxiety</td>
<td>-0.14</td>
<td>-0.32***</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning(N)</td>
<td>-0.54**</td>
<td>-0.11</td>
<td>0.20</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Learning(R_GEN)</td>
<td>-0.45**</td>
<td>-0.30*</td>
<td>0.04</td>
<td>0.06</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* $p < 0.05$  ** $p < 0.01$

Associations were similar to those observed previously, with a high negative correlation between computer confidence and anxiety ($r = -0.32, p = 0.010$). There was again a significant negative correlation between original knowledge (as measured by summing pre-test scores over the two topic areas) and learning using...
both the N and R_GEN environments \( r = -0.54, p < 0.001 \) and \( r = -0.45, p < 0.001 \), respectively). In this study, however, there was also a significant negative correlation between computer confidence and learning achieved in the R_GEN environment that required the students to respond \( r = -0.30, p = 0.015 \).

The responses to the survey about the advantages and disadvantages of this particular type of learning experience were combined over both studies and summarised in Figs 3 and 4. Student suggestions about how much of their present lectures should be replaced using similar techniques are summarised in Fig. 5.

Fig. 3 Summary of the students’ different opinions as to the main disadvantage of the online learning experience.

Fig. 4. Summary of the students’ different opinions as to the main advantage of the online learning experience.

Only 16 of the students reported accessing the learning environments at home. Mean
scores for learning achieved by these students using the two environments were compared with those achieved by students learning within college. Meaningful statistical analysis was not possible, since these two types of user were not equally distributed amongst the four experimental groups that underpinned the balanced design of the study. However, differences between environments ran in the same direction for both types of user, i.e. more appeared to have been learnt from the R_GEN environment.

Discussion

Although it was considered possible that the A_MCQ condition might not improve learning, its apparent detrimental effect was unexpected. It is possible that the MCQ format of the questions may have increased the cognitive load (Thuring et al., 1995) by presenting unrelated issues that might otherwise not have been considered or, by reducing the number of options, decreased the challenge, engagement and learning.

However, it seems more likely that the reduction in learning observed in subjects using the A_MCQ environment was due to questions focusing only upon the first part of the problem solving process (the analysis). Comments arising during interviews with students after their experience indicated that the questions encouraged them to consider the analysis more and its relationship to the solution less. As one student put it: ‘I’m afraid I just went through the multiple-choice questions and every time I dealt with those then the answer (solution) would appear and I’d just go past that because I really wanted to get on . . . ’ (author’s words in italics). In studies such as Felker & Dapra (1975), higher-order comprehension questions successfully enhanced concept learning but these were defined as requiring the subject to either (a) identify a new instance of a concept and discriminate it from
non-instances, or (b) in applying a principle, select the proper instance of the consequent conditions when given the antecedent conditions. The A_MCQ environment, however, required subjects only to analyse the problem and thereby identify clearly the antecedent conditions. It was hoped, originally, that this would prompt the learners to consider more carefully how these conditions were related to the consequent solution revealed on the next screen. However, by focusing attention upon an analysis not yet fully related in the learner’s mind to the subsequent solution which followed, a depressive effect may have occurred reducing the attention paid to the subsequent text encoding the solution. Similar negative effects have been observed in some studies involving prequestions (e.g. Anderson & Biddle, 1975).

An informal inspection of the students’ own rules generated in the second study revealed that many were imperfect and unable to account sufficiently for all the examples or provide appropriate answers to all the post-test questions. On occasions when such rules were generated, they could be linked to difficulties in the post-test. For example, many students did not differentiate between the usefulness of the hole punch and the paper drill for making holes in thin sheet (the paper drill places a hole anywhere – the hole punch only at the edge of the sheet). These students were later more likely to choose the inappropriate tool for making holes in thin sheet in the post-test. Despite such examples of inaccuracy in rule generation, however, concept learning in the R_GEN environment was significantly improved, presumably due to the generation effect discussed above. The negative correlation between anxiety and computer confidence, evident in both studies, has been commonly reported elsewhere (e.g. Newby & Fisher, 1997). The negative correlation between computer confidence and learning achieved using the R_GEN environment is perhaps more surprising. However, this was the environment that involved the inputting of text via the keyboard and this was perhaps the greatest interaction with the computer encountered when accessing the three environments. Those students with less keyboard skills may have taken more care when compiling and entering their rules, and thus considered the content of their responses more carefully. Similar results have been reported by Levine & Donitsa-Schmidt (1997) who found that computer confidence can have a negative effect upon commitment to computer learning.

The negative correlation between pre-test scores and learning indicates that, in both studies, those who benefited most were those who knew less to begin with. This is contrary to findings by some other studies (e.g. Recker & Pirolli, 1995) but such a relationship may be very dependent upon the level of challenge provided by the materials and task. There may even have been a ceiling effect which did not allow the more able students to achieve improvements comparable with their less able colleagues. However, box plots did not identify convincingly distorted distributions in upper pre-test or post-test scores. Further analysis of scores derived from students appearing in the lower quartile of pre-test scores also showed a high negative correlation between pre-test scores and learning and analysis of scores derived from students in the upper quartile still showed significant increases in learning. This may, therefore, be another example of how constrained systems offering only limited user-control favour the less able, echoing the findings of some other studies (e.g. Shin et al., 1994).

It was not possible in either study to control the surrounding environment in which the students carried out their learning. Some students preferred to use the materials on campus-based computers and others preferred to access them via
telephone modems at home. Speed of access in the latter case would have been restricted and dependent upon the time of day. In the second study, it was noted that mean differences in scores amongst home and college-based users both tended to favour the R_GEN environment as more effective. Such a consistency of outcome would reflect the findings of Van den Berg & Watt (1991), whose study indicated that the situational effects upon computer-assisted learning, if any, appear small.

The flexibility afforded by the approach was clearly popular, with more than a third of the students in the second study requesting that 40–50% of their lectures be substituted by such methods of learning. This is reflective of the generally positive student response highlighted by Tait (1998).

While the first study provides a cautionary lesson about good intentions having unwelcome effects, the second study demonstrates how gathering the type of responses that may suitable for the monitoring of learning can also enhance it directly. However, no formal evaluation of the effectiveness of the approach in terms of monitoring has been made here, since the present study has focused only upon the immediate learning effects of two types of questioning upon concept learning within one particular context. It remains to be seen whether the twin aims of monitoring the learner and directly enhancing their learning will have similar implications for the design of questions set in hypertext.

References


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