Instructional methods and cognitive and learning styles in web-based learning: report of two randomised trials

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CONTEXT Adapting web-based (WB) instruction to learners’ individual differences may enhance learning.

OBJECTIVES This study aimed to investigate aptitude–treatment interactions between learning and cognitive styles and WB instructional methods.

METHODS We carried out a factorial, randomised, controlled, crossover, post-test-only trial involving 89 internal medicine residents, family practice residents and medical students at 2 US medical schools. Parallel versions of a WB course in complementary medicine used either active or reflective questions and different end-of-module review activities (‘create and study a summary table’ or ‘study an instructor-created table’). Participants were matched or mismatched to question type based on active or reflective learning style. Participants used each review activity for 1 course module (crossover design). Outcome measurements included the Index of Learning Styles, the Cognitive Styles Analysis test, knowledge post-test, course rating and preference.

RESULTS Post-test scores were similar for matched (mean ± standard error of the mean 77.4 ± 1.7) and mismatched (76.9 ± 1.7) learners (95% confidence interval [CI] for difference −4.3 to 5.2, P = 0.84), as were course ratings (P = 0.16). Post-test scores did not differ between active-type questions (77.1 ± 2.1) and reflective-type questions (77.2 ± 1.4; P = 0.97). Post-test scores correlated with course ratings (r = 0.45). There was no difference in post-test sub-scores for modules completed using the ‘construct table’ format (78.1 ± 1.4) or the ‘table provided’ format (76.1 ± 1.4; CI −1.1 to 5.0, P = 0.21), and wholist and analytic styles had no interaction (P = 0.75) or main effect (P = 0.18). There was no association between activity preference and wholist or analytic scores (P = 0.37).

CONCLUSIONS Cognitive and learning styles had no apparent influence on learning outcomes. There were no differences in outcome between these instructional methods.

KEYWORDS multicentre study [publication type]; randomised controlled trial [publication type]; *Internet; *education, distance; crossover studies; *cognition; clinical competence/*standards; learning; education, medical/*methods; United States.

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INTRODUCTION

Although much has been written evaluating web-based learning (WBL)1 and justifying its use compared with alternative media formats,2 more evidence is needed regarding which instructional designs actually work and under which circumstances.2–4 Adapting WBL to learners’ cognitive or learning styles (CLSs) may facilitate learning.4 However, justifying such adaptations requires evidence of an aptitude–treatment interaction5 in which learners with style 1 learn better with method A than method B, while learners with style 2 learn better with method B.
Overview

What is already known on this subject

Little research has investigated ways to improve instructional design in web-based learning. Adaptation to cognitive and learning styles has been suggested to enhance learning, but evidence is scarce.

What this study adds

Matching question type (active versus reflective) to active or reflective learning styles did not improve learning. Constructing a summary table to organise knowledge did not affect knowledge test scores, and there was no significant interaction with wholist-analytic styles. Test scores correlated with course ratings.

Suggestions for further research

Further research might explore ways to improve web-based instructional designs, and investigate theory-based adaptations of web-based learning to cognitive style, learner prior knowledge or training level, and learner motivation.

Study 1

Question type and active or reflective learning style

In theory, case-based questions should improve learning by activating prior knowledge, providing a learning context, and facilitating elaboration. Although the evidence is mixed, research in computer-assisted instruction (CAI) appears to support the theory. However, different question types may have different educational benefits. Open-ended questions can enhance learning by facilitating reflection and analysis from multiple viewpoints, whereas multiple-choice questions (MCQs) encourage learners to actively apply what has been learned and commit to a course of action. We found no studies comparing different question types.

Kolb’s learning model includes the description of active experimentation and reflective observation learning styles. Active learners prefer practical application of information they have received, whereas reflective learners prefer to internalise information and examine it from different perspectives. We might expect active learners to learn better when using MCQs, and reflective learners to favour reflective questions. No studies have, to our knowledge, investigated this proposition.

We hypothesised that, in a WBL course, medical students and residents matched to question type according to their active or reflective learning styles will have higher knowledge test scores and higher course satisfaction ratings than those who are mismatched.

Study 2

Review activity format and wholist or analytic cognitive style

Cognitive psychology suggests that learning involves more than the mere acquisition of information. Rather, useful learning requires that learners build effective knowledge structures by organising information in a meaningful way. Some CAI research suggests that learning improves when learners impose their own knowledge structure rather than having it provided for them. One method to encourage learner structuring of knowledge is for learners to outline the structure of an information database, populate the database with information, and then answer questions while analysing and recognising patterns within the information. Although grounded in theory, the literature supporting this method consists exclusively of descriptive studies.

Riding has suggested that all cognitive styles are encompassed by 2 dimensions: wholist-analytic and verbaliser-imager. The wholist-analytic construct characterises how an individual perceives the world, whether as a unified whole or as a collection of individual parts. Wholists would probably benefit from a review activity such as database construction to help them structure their thinking and perceive the relationships among discrete data. Analytics, already proficient at imposing their own structure, are less likely to benefit from such an activity and in fact may find it impedes their learning.
We hypothesised that:

1. medical students and residents with a wholist cognitive style who complete a database construction activity in a web-based course will have higher knowledge test scores than wholists who do not complete this activity, and analytics who complete the activity will have lower scores than those who do not (interaction), and

2. medical students and residents with a wholist style will prefer the construction activity, whereas analytics will prefer no activity.

**METHODS**

We conducted a randomised, controlled, post-test-only trial using a factorial design. The independent variables were ‘matched or mismatched to learning style’ and ‘review activity format’. Randomisation, stratified by training programme and year of training, was carried out using MINIM (London Hospital Medical College, London, UK).

All Year 3 and 4 medical students at the University of Illinois at Chicago School of Medicine and the Mayo Medical School and all residents in the Mayo-Rochester internal medicine and family medicine residency programmes were eligible to participate. All participants gave written consent.

**Interventions**

Three WBL modules on complementary and alternative medicine (CAM) were developed, specifically on background, dietary therapies, and non-dietary therapies. Course development and organisation have been detailed elsewhere. Each module consisted of 1–3 ‘case series’ followed by a review activity. Each case series began with brief patient cases followed by didactic information, after which each case was presented again along with 2–4 self-assessment questions.

Two versions of each module were created, the first with active questions and the second with reflective questions. Active questions were MCQs that provided learners with feedback after they had responded. Learners answering incorrectly were required to answer the question again until correct. Reflective questions were open-ended and encouraged the learner to look at the case and content from more than 1 viewpoint, contrast different cases and recognise uncertainties. No answers or feedback were provided. Learners were randomly matched or mismatched, based on active or reflective learning style, to use either active or reflective questions.

The review activity also had 2 levels: ‘construct table’ and ‘table provided’. The dietary therapies and non-dietary therapies modules were each developed with both review activity formats. The ‘construct table’ activity asked learners to construct and review a summary table:

‘Create a table that outlines the key points of each therapy discussed in this module. You might wish to contrast, for example, the purported benefits of each therapy, the evidence supporting these benefits, and/or the potential side-effects. There are probably other themes that you will want to include. Once you have created your table, take some time to study the relationships among the various therapies.’

The ‘table provided’ activity presented a table outlining key module content and instructed learners to:

‘Review the table below. Take time to study the relationships among the various therapies – indications, evidence, side-effects, etc.’

Learners were randomly assigned to ‘construct table’ for the dietary therapies module and ‘table provided’ for the non-dietary therapies module, or vice versa. Module sequence was also randomised. Online supplementary Fig. S1 illustrates the differences between the 4 intervention formats.

**Outcomes and instruments**

A baseline survey assessed demographics and CAM-related behaviours.

One primary outcome, knowledge, was determined using a post-test containing 48 case-based MCQs (development described previously) designed to assess application of knowledge. The post-test was repeated after a 3-month delay (delayed test). Participants received answers only after the delayed test.

The other primary outcomes, course satisfaction and review activity preference, and additional secondary course evaluation outcomes were determined using an end-of-course survey. A follow-up survey carried out 3 months later assessed the impact of the course on behaviours.

Felder and Solomon’s Index of Learning Styles (ILS) consists of 11 forced-choice items for each of...
4 dimensions: active–reflective, sensing–intuitive, visual–verbal and sequential–global. Scores range from −11 to +11 in increments of 2 (−11, −9…9, 11). Negative scores indicate 1 learning style along a dimension (e.g. ‘active’), whereas positive scores indicate the complementary style (e.g. ‘reflective’). Evidence supports the validity of ILS active–reflective scores among internal medicine residents and medical students.19

Riding’s Cognitive Styles Analysis (CSA; Learning and Training Technology, Stourbridge, UK) measures wholist–analytic and verbaliser–imager cognitive styles. Although psychometric data on CSA scores are limited,19,20 the CSA is used extensively in CAI research. We used thresholds suggested in the instrument guidebook for classifying learners’ style (wholist ≤1.02, analytic > 1.35; verbaliser ≤0.98, imager > 1.09).

Data analysis

All analyses were intention-to-treat, all comparisons were 2-sided and P-values < 0.05 were considered statistically significant. Analyses were performed using sas 9.1.

For study 1, unadjusted knowledge post-test scores were compared using the t-test. Secondary analyses used general linear models (GLMs) to adjust for variables of interest. Subgroup analyses for statistically significant models were performed using Fisher’s method of least significant difference. A sample size of 160 participants was expected to provide 87% power to detect a difference of 5%, which we considered a meaningful difference. The Wilcoxon rank-sum test was used to compare course satisfaction and question type effectiveness between groups. Because available non-parametric techniques do not provide the capacity to perform additional multivariate adjustments, GLMs were used to compare groups while adjusting for variables of interest. The fit of this parametric model was assessed and deemed adequate. The target sample size was expected to provide > 95% power to detect a difference of 0.5 preference scale points (6-point scale).

Baseline demographics and CAM-related behaviours were compared between groups and/or over time using the chi-square test or Fisher’s exact test. Pearson correlations were computed between overall course ratings and knowledge post-test scores. Further associations between post-test scores, course ratings and CLSs were evaluated using GLMs.

RESULTS

A total of 89 students and residents consented to participate and completed the course. Demographics and flow of study participants are shown in online supplementary Table S1 and Fig. S2. Fourteen participants (16%) had no prior experience with WBL. Thirty-three (37%) reported using a CAM therapy and 20 (22%) reported referring a patient to a CAM provider in the past 6 months. Cronbach’s α for the post-test was 0.79. Individual and simultaneous adjustment for gender, training programme, year of training, and either review activity format (for study 1) or module assignment, module sequence and matching/mismatching to question type (for study 2) had no significant effect on any reported analyses except as noted.

Study 1

Effect of matching

Knowledge post-test scores were similar for matched (mean ± standard error of the mean 77.4 ± 1.7) and mismatched (76.9 ± 1.7) learners (95% confidence interval [CI] for difference −4.3 to 5.2, P = 0.84). Likewise, delayed test scores were not significantly different between matched (62.2 ± 1.7) and mismatched (65.6 ± 1.9) learners (P = 0.19).
Using a scale ranging from 1 = poor to 10 = excellent, the mean course rating was 7.7 ± 0.2. The difference in course ratings between matched (8.0 ± 0.2) and mismatched (7.5 ± 0.3) learners was not significant (P = 0.16). The CI for the difference (using GLM) was −0.2 to 1.2. Overall, learners felt that the self-assessment questions were effective (mean score 4.7 ± 0.1, using a scale ranging from 1 = ineffective to 6 = effective) and should be kept as part of the modules (4.8 ± 0.1). There was no significant difference in question effectiveness between matched (4.6 ± 0.2) and mismatched (4.7 ± 0.2) learners (P = 0.46).

**Effect of question type**

Looking at question type as a main effect, learners using active questions had post-test scores (77.2 ± 1.4; CI for difference −4.9 to 4.7, P = 0.97). Course ratings were also similar between those using active (7.5 ± 0.3 [10-point scale]) and reflective (7.8 ± 0.2) questions (CI for difference −1.0 to 0.4, P = 0.53). However, learners using active questions rated questions as more effective (5.0 ± 0.1 [6-point scale]) than did those using reflective questions (4.4 ± 0.2; P = 0.017), and those using active questions felt more strongly that questions should be kept in modules (5.1 ± 0.2 versus 4.6 ± 0.2; P = 0.029).

**Additional analyses**

Post-test scores correlated with course ratings (r = 0.45, P < 0.001), with higher post-test scores among those who rated the course highly. Those who rated the course at or above the median rating (8) had higher scores (80.5 ± 1.1) than those who rated the course below the median (71.4 ± 2.4; P < 0.001). The difference in post-test scores between matched and mismatched learners remained non-significant (P = 0.62) after adjustment for course ratings.

Style classifications for the active—reflective, sensing—intuitive, visual—verbal, sequential—global, wholist—analytic and verbaliser—imager dimensions had no significant association with course rating (P > 0.13) or post-test score (P > 0.18), and there was no interaction with matching or mismatching.

On the 3-month post-course survey, 28 of 39 (72%) matched and 26 of 42 (62%) (P = 0.35) mismatched learners reported that they had asked patients about CAM use more than 25% of the time, and 16 (41%) of matched and 17 (40%) (P = 0.96) of mismatched participants reported that they had recommended a CAM therapy to a patient at least once since starting the course.

**Study 2**

**Impact on post-test scores**

After adjusting for differences among modules (the non-dietary therapies module had significantly lower scores than the dietary therapies module, P < 0.0001; module sequence had no effect, P = 0.66), there was no significant difference in post-test subscores between modules completed using the ‘construct table’ (78.1 ± 1.4) or ‘table provided’ (76.1 ± 1.4) activities (CI for difference −1.1 to 5.0, P = 0.21). There was no significant interaction between wholist—analytic scores and review activity (b_{construct} = 1.6, b_{provided} = −0.8; P = 0.49 for difference in slopes) on post-test subscores, nor did wholist—analytic styles have a main effect on this outcome (P = 0.18) (Table 1).

Looking at delayed test subscores, there was no significant difference between ‘construct table’

<table>
<thead>
<tr>
<th>Table 1 Knowledge post-test subscores</th>
<th>Wholist Style</th>
<th>Intermediate Style</th>
<th>Analytic Style</th>
<th>Styles Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities Combined,* mean ± standard error</td>
<td>80.4 ± 2.4</td>
<td>75.3 ± 1.9</td>
<td>78.9 ± 1.9</td>
<td>77.1 ± 1.2</td>
</tr>
<tr>
<td>Construct table, mean ± standard error</td>
<td>80.6 ± 2.9</td>
<td>75.4 ± 2.3</td>
<td>80.3 ± 2.3</td>
<td>78.1 ± 1.4</td>
</tr>
<tr>
<td>Table provided, mean ± standard error</td>
<td>80.2 ± 2.8</td>
<td>75.1 ± 2.2</td>
<td>77.5 ± 2.3</td>
<td>76.1 ± 1.4</td>
</tr>
<tr>
<td>Difference (construct table – table provided), mean (95% CI)</td>
<td>0.4 (−5.8, 6.7)†</td>
<td>0.3 (−4.7, 6.2)†</td>
<td>2.8 (−2.3, 7.8)†</td>
<td>2.0 (−1.1, 5.0)‡</td>
</tr>
</tbody>
</table>

These scores reflect a subset of questions testing content unique to either the Dietary or Non-dietary module (see text for details)

* P = 0.18 for comparison among styles, and thus individual P-values are not reported. Differences and 95% confidence intervals are as follows: analytics less intermediates 3.7 (−1.6, 8.9); analytics less wholists −1.5 (−7.4, 4.5); intermediates less wholists −5.2 (−11.1, 0.8)

† P = 0.75 for interaction between review activity and wholist-analytic styles, and thus individual P-values are not reported

‡ P = 0.21
Figure 1 Preference for review activity stratified by wholist–analytic styles

(63.6 ± 1.6) or ‘table provided’ (64.9 ± 1.6; CI for difference −4.9 to 2.5, \( P = 0.47 \)). There was no significant interaction between wholist–analytic scores and review activity (\( P = 0.97 \)) or main effect from wholist–analytic styles (\( P = 0.79 \)) on delayed test subscores.

Impact on preference

The mean review activity preference was 3.6 ± 0.2 (CI 3.3–3.9) on a scale where 1 = definitely prefer ‘construct table’ and 6 = definitely prefer ‘table provided’ (\( P = 0.59 \) for comparison with scale midpoint [3.5]). There was no significant association between preference and wholist–analytic scores (\( b = 0.3, \) CI −0.4 to 1.0, \( P = 0.37 \)). However, preference was associated with wholist–analytic style classifications (\( P = 0.001 \)) (Fig. 1), indicating that on average learners with an intermediate style preferred the ‘construct table’ activity (2.9 ± 0.2) and wholist (3.8 ± 0.3) and analytic (4.3 ± 0.3) learners preferred the ‘table provided’ activity (\( P < 0.001 \)) comparing intermediate with analytic; \( P = 0.036 \) comparing intermediate with wholist; \( P = 0.23 \) comparing wholist with analytic). Medical students preferred the ‘construct table’ activity (3.2 ± 0.2) and residents preferred the ‘table provided’ (4.0 ± 0.2; \( P = 0.008 \)).

The ‘construct table’ format was felt to be more effective than the ‘table provided’ format (mean rating 2.9 ± 0.2; \( P < 0.001 \)). Wholist–analytic styles were associated with this outcome (\( P = 0.003 \)): learners of intermediate style favoured the ‘construct table’ (2.4 ± 0.2) slightly more than wholists (2.9 ± 0.3; \( P = 0.17 \)) and significantly more than analytics (3.5 ± 0.2; \( P = 0.001 \)). The difference between wholists and analytics was not significant (\( P = 0.80 \)).

Post-test scores were not significantly different between learners preferring the ‘construct table’ (75.8 ± 1.7) versus the ‘table provided’ activity (78.7 ± 1.6; CI for difference −7.4 to 1.5, \( P = 0.19 \)).

Exploratory analyses

There was no significant association between active–reflective, sensing–intuitive, visual–verbal, sequential–global or verbaliser–imager styles and post-test subscores (\( P > 0.15 \)). Active learners preferred the ‘construct table’ (3.2 ± 0.3) and reflective learners preferred the ‘table provided’ format (3.8 ± 0.2), but the difference was not significant (\( P = 0.072 \)). Sensing–intuitive, visual–verbal, sequential–global and verbaliser–imager styles were not associated with review activity preference (\( P > 0.13 \)).

DISCUSSION

Study 1 hypothesised that matching learners to different types of case-based questions according to active or reflective learning styles would favourably influence knowledge post-test scores and course ratings. No evidence was found to support either hypothesis, Study 1 also compared 2 instructional methods, namely active and reflective question types. Post-test scores and course ratings were similar for both, although learners using MCQs rated question effectiveness more highly than did those using reflective questions. The lack of difference between these interventions may not be unexpected, as the cases were identical and the variation in question format was designed to target individual learning styles rather than improve the instructional method. This nonetheless holds implications for instructional design in CAI. A recent study\(^6\) showed that self-assessment questions improve knowledge scores in WBL; the present study builds upon this by demonstrating that question type does not appear to matter.

Study 2 hypothesised that wholist–analytic cognitive styles would interact with review activity format to favourably influence post-test scores. No evidence was found to support this interaction or a main effect of wholist–analytic styles on post-test scores. We also hypothesised that wholists would prefer the ‘construct table’ activity and analytics would prefer the ‘table provided’ format. On average, those with intermediate wholist–analytic style preferred the ‘construct table’ format and wholists and analytics preferred the ‘table provided’. However, Fig. 1 shows that many intermediate learners actually preferred the ‘table provided’ and many with wholist or analytic...
styles preferred the ‘construct table’ format. In addition, regression showed no significant association between preference and wholist–analytic scores. Thus, there seems to be no consistent influence of wholist–analytic style on format preference.

Study 2 can also be viewed as comparing 2 instructional methods, using a ‘construct table’ and a ‘table provided’ format, respectively. The lack of benefit from the ‘construct table’ activity is surprising, as this instructional method was expected to stimulate cognitive processing and thus improve learning as well as develop metacognitive skills.7 Perhaps the act of table creation adds little to the value of a review activity, or perhaps the educational efficacy of the primary instructional method (case-based learning) precluded additive benefit from this activity. Alternatively, learners may not have completed the activity as assigned. Another explanation is suboptimal implementation; perhaps asking questions as part of the review activity would have enhanced learning13 (although this would have enhanced the ‘table provided’ activity, too). Finally, the introductory nature of the course might not have demanded the deep, critical thinking that would have exploited the ‘construct table’ activity.

We believe the most likely explanation for the failure to confirm aptitude–treatment interactions in either study is that the overall effectiveness of the instructional design overshadowed the influence of CLS. Other possible explanations include restriction of range, high learner motivation, the ability of high-achieving learners to adapt to various instructional designs, or limitations in the assessment of CLS. Regarding the latter, a recent study19 showed that although ILS active–reflective scores had acceptable test-retest reliability, up to 10% of learners changed from active to reflective classification (or vice versa) upon retesting. This presents a challenge when using style classifications for decisions such as matching. Similarly, recent research has called into question the reliability of CSA scores.21,22

The absence of interaction between CLSs and instructional methods does not necessarily mean that interaction would not be found with other instructional methods or in another course. However, these findings agree with authors who have suggested that once effective instructional methods are employed, intellectually capable and motivated learners may learn equally well, regardless of CLS.23,24 In both WBL9 and non-WBL5,25 education, associations between learning outcomes and CLSs are occasionally found, but interactions are rare. Although the lack of supporting evidence may be merely the result of a paucity of appropriate research, existing evidence6,8,23,24 suggests that the influence of styles is at best weak and inconsistent. Other limitations in WBL adaptations include limitations in aptitude assessments, practical limitations in application,5 and the complexity of human interactions.26 Thus, adaptations based on CLS, although theoretically useful, may not substantially enhance WBL in medical education.

Those who rated the course more highly had higher post-test scores, and course ratings explained 20% of the variance in post-test scores ($R^2 = 0.20$). Others have reported similar findings.27 Assuming that learners’ baseline knowledge was similar across course ratings, this suggests that those who gave higher course ratings learned more, which leads us to speculate regarding the link between satisfaction and learning. Theories of motivation suggest a reciprocal relationship between self-efficacy and accomplishment (i.e. learning).28,29 Furthermore, Gagné et al. proposed that matching learner needs and instructional design will improve learning.30 Thus, satisfaction may enhance motivation and in turn engender higher achievement. Another explanation is that course ratings were possibly biased by post-test performance.

This study did not achieve the target sample size. However, the CIs for most analyses exclude or nearly exclude differences as large as our a priori level of educational significance (5% difference in scores, 1 point in course ratings, and 0.5 points in activity preference), suggesting that the failure to detect an effect did not result from lack of power. The inclusion of learners of intermediate style and the above-noted weaknesses in CLS assessments are further limitations. Finally, these results may not apply to learners with different baseline knowledge, motivation or other characteristics. We recruited participants from another institution to enhance generalisability, but that sample was small and potentially biased. Although we did not administer a pre-test, a separate study found that this course improved knowledge test scores by 50% (effect size 2.5), compared with a non-randomised, no-intervention control.17

Future research might replicate this study or explore other potential interactions between CLSs and WBL instructional methods. Such research will require valid assessments of CLSs, and studies to evaluate and refine CLS instruments are necessary. Research could also evaluate the effectiveness of various instructional methods as applied to specific learners.
and learning settings. This study suggests that adapting WBL to learner motivation might be effective, and early efforts have shown guarded success. The finding that medical students preferred the ‘construct table’ format and residents preferred the ‘table provided’ warrants further study, as does the fact that the ‘construct table’ activity was felt to be more effective overall.

In summary, this study found no evidence to support hypothesised interactions between CLSs and instructional methods. Although it reflected only 2 interventions, the findings suggest that adaptations based on CLSs may be less useful than previously thought.

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Conflicts of interest: none.

Ethical approval: this study was deemed exempt by the Institutional Review Board at the Mayo Clinic and the University of Illinois at Chicago. All participants provided written consent.

REFERENCES


SUPPLEMENTARY MATERIAL

The following supplementary material is available for this article:

Table S1. Characteristics of study participants.

Figure S1. Representative screen shots.

Figure S2. Flow of study participation.

This material is available as part of the online article from:


(This link will take you to the article abstract).

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