Original article

Learning styles and formative assessment strategy: enhancing student achievement in Web-based learning

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Abstract The purpose of this research was to investigate the effects of formative assessment and learning style on student achievement in a Web-based learning environment. A quasi-experimental research design was used. Participants were 455 seventh grade students from 12 classes of six junior high schools. A Web-based course, named BioCAL, combining three different formative assessment strategies was developed. The formative assessment strategies included Formative Assessment Module of the Web-Based Assessment and Test Analysis system (FAM-WATA) (with six Web-based formative assessment strategies), Normal Module of Web-Based Assessment and Test Analysis system (N-WATA) (only with partial Web-based formative assessment strategy) and Paper and Pencil Test (PPT) (without Web-based formative assessment strategy). Subjects were tested using Kolb's Learning Style Inventory, and assigned randomly by class into three groups. Each group took Web-based courses using one of the formative assessment strategies. Pre- and post-achievement testing was carried out. A one-way ANCOVA analysis showed that both learning style and formative assessment strategy are significant factors affecting student achievement in a Web-based learning environment. However, there is no interaction between these two factors. A *post hoc* comparison showed that performances of the FAM-WATA group are higher than the N-WATA and PPT groups. Learners with a 'Diverger' learning style performed best followed by, 'Assimilator', 'Accommodator', and 'Converger', respectively. Finally, FAM-WATA group students are satisfied with six strategies of the FAM-WATA.

Keywords biology, e-learning effects, Kolb's learning style, middle school, WATA system, Web-based formative assessment.

Introduction

As information technology (IT) matures, Web-based learning has gradually come into its own. However, it is a challenge to develop Web-based learning that is suitable for the varied needs of different students. Successful learning stems from the conformity between student needs and the learning environment (Federico 2000). Previous research has shown that student learning is influenced by numerous factors, such as age, gender, and socioeconomic status. In recent years, learner attributes such as affective expression (e.g, interest, attitude, or motivation), learning experiences (such as misconceptions, mental models or alternative mental structures), and learning characteristics (such as cognitive style or learning

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style) have gradually become the focus in the field of science education. Learning styles are considered as one of the more important factors that influence e-learning (Ford & Chen 2000). Furthermore, the design strategy of the teaching environment is also seen as a key factor that affects student learning. Teaching activities and strategies that are tailored to individual difference can propel students to higher levels of learning.

Review of literature

Learning styles

Learning style is one of the important factors that affect personal academic competence (Kolb 1984). Scholars define learning style differently. Kolb (1976) saw learning style as the unique learning method presented by the learner during the learning process and situation. Butler (1987) argued that learning style shows a natural method, which is the easiest and most effective, and is used by the learner to realize the self, the environment, and relation between self and environment. McDermott and Beitman (1984) indicated that learning style is the unique way of learning expressed in the learning process, which includes observable strategies for problem solving, decision-making behavior, restrictions encountered in the learning situation and reaction under the expectations of others. Gregorc (1979) and Entwistle (1981) pointed out that learning style is learner preference for certain learning strategies in a given learning situation. Canfield and Canfield (1988) thought that learning style is the peculiarity expressed by learners while accepting stimulation or solving problems under learning conditions. Keefe (1991) defined learning style as 'characteristic cognitive, affective, and psychological behaviours that served as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment'. In sum, there is currently no widely accepted definition of what learning style is.

Among the many ways to measure learning style, the most commonly used instrument relevant to e-learning is Kolb's Learning Style Inventory (LSI) (Dringus & Terrell 1999; Federico 2000; Terrell 2002). The Kolb's LSI was developed in the early 1970s. The model focuses on how individuals perceive and process information. Kolb (1984) built the theoretical framework of LSI based on experiential learning theory (ELT), which considers learning a successive learning process cycle that iterates continuously. Kolb (1976) divided the learning process cycle into four learning modes in term of information perception and processing by learners: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). When students are tested with the LSI, they will receive a score in each of the four learning modes. Through a graphic profile plotted on the Learning-Style Type Grid, learners may be identified with one of the following four styles: namely, Diverger, Assimilator, Converger, and Accommodator (see Fig 1). The Diverger prefers a combination of CE and RO. They are best at viewing concrete situations from different points of view, and tend to be imaginative and emotional, and like to generate ideas. Such learners have broad cultural interests and tend to specialize in the arts, counsellors, specialists and personnel managers. The Assimilator prefers a combination of RO and AC. Such learners tend to be less interested in people and more concerned with abstract concepts. They are best at putting information into logical, detail form. As a result, they are more interested in basic sciences and mathematics rather than the applied sciences. The Converger prefers combination of AC and AE. They are best at finding practical uses for ideas and theories, and tend to use hypothetical-deductive reasoning to solve specific problems and prefer to deal with things rather than people. Such learners are often found in the engineering professions. The Accom-

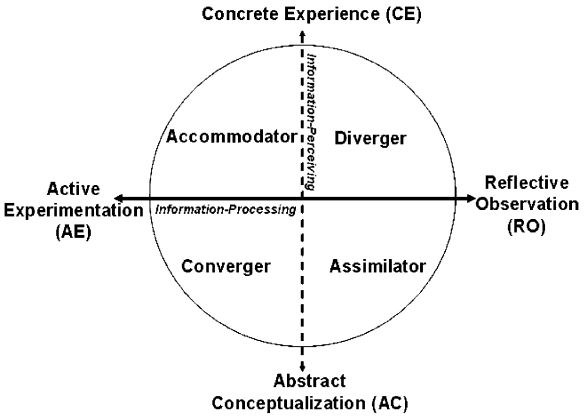

Fig 1 Kolb's learning styles and learning modes (Adapted from Kolb 1984).

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modator prefers combination of CE and AE. These style persons tend to rely heavily on information provided by others rather than on their own analysis. Such learners are typically interested in marketing or sales. The Kolb' LSI can be used to identify these four learning modes and learning styles (Kolb 1984, 1985).

Learning styles are also considered a valid predictor of success in a Web-based learning environment (Ford & Chen 2000). A number of scholars have applied Kolb's learning style theory to study the effects of e-learning and hypermedia learning, and most of them indicate that learning styles are a key factor in the effectiveness of learning (Kolb & Kolb 2003). However, most studies on relationships between learning style and e-learning effects have been done on college- and graduate-level students (Rasmussen & Davidson-Shivers 1998; Dringus & Terrell 1999; Terrell 2002; Jones *et al*. 2003). Only a handful of studies have been done on the middle and high school level. Yoon (2000) conducted a study to determine the relationship between student learning styles, gender, goal accomplishment styles, and academic achievement in geography. The results showed that middle school student learning styles and goal accomplishment styles are capable of predicting academic achievement in geography.

Which learning styles perform better during e-learning? The literature seems to contain no clear answer to the question. Chou and Wang (2000) studied senior high school student e-learning effects and discovered that Accommodators and Convergers (AE learning style) have higher e-learning effectiveness, and that their e-learning methods and learning styles have a significant interaction. Gunawardena and Boverie (1993) studied interaction among method of instruction, learning style, and computer-mediated communication in distance learning. Their results show that learning style does not influence how students interact with media and methods of instruction. However, Accommodators were the most satisfied and Diverger subjects were the least satisfied with class activities. Sein and Robey (1991) found that Convergers performed better than subjects with other learning styles in computer training methods. In sum, research reports show inconsistent results of performance among the different learning styles. Many factors might lead to such results. According to Kolb (1984), learning style differences may occur depending on learning task, environment, time, student exigency level, and other factors.

It is clear that learning styles decisively influence e-learning effectiveness. Scholars agree that understanding student learning styles can help improve instructional planning and implementation and enhance student learning, especially for those who want to use IT in their classes (Federico 2000). However, currently research is unable to confirm what type of course design best suits each learning style. This requires further exploration.

Formative assessment

Many researchers (Brown & Knight 1994; Black & William 1998; Bransford *et al*. 2000; Buchanan 2000; Velan *et al*. 2002; Henly 2003) have emphasized the importance of formative assessment in student learning achievement, but studies on formative assessment strategy and its effects are not nearly as plentiful as they should be.

A learning environment with formative assessment has numerous benefits for learners. Many studies indicate that integrating the e-learning environment with Web-based assessment has positive results (Velan *et al*. 2002; Henly 2003). Online assessment has advantages over traditional classroom assessment. Zakrzewski and Bull (1999) found that online tests have at least three advantages for students. Students can take the assessment at any time, they can take it repeatedly, and it can provide instant feedback that helps remedy weaknesses in their learning abilities. They also indicate that student anxiety can be reduced if they take the formative assessment before summative tests. Clariana (1997) suggested that online assessments can be adapted to student leaning styles.

Formative assessment refers to those activities that are used to help students learn. These types of activities include short tests and quizzes, question and answer in the lesson, assignments, homework, and so on. Bransford *et al*. (2000) suggested that the learning environment must consider centralization in assessment, in particular to value formative assessment. They further noted that formative assessment designs should be able to engage student attention and engender student commitment to self-evaluation, enhancing learning effectiveness. A learning environment with formative assessment has many benefits to

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learners. Buchanan (2000) showed that a Web-based formative assessment strategy is able to improve student learning interest and student scores. Seale *et al*. (2000) found that formative assessment allows students to assess their own progress and understanding.

Scholars have also made detailed evaluations of what types of formative assessment strategies work best. Buchanan (2000) argued that 'repeat the test' is an important design of Web-based formative assessment strategy. However, he noted, this strategy design must be implemented in conjunction with the functions of 'provide with no answer' and 'instant feedback' so that the Web-based formative assessment will be more beneficial. For such feedback to be effective it needs to be provided early in the learning process (Brown & Knight 1994) and give guidance for improving performance (William & Black 1996, p. 543).

Many Web-based formative tests provide useful strategies for enhancing student learning. For example, WebMCQ (http://www.webmcq.com/) provides a final score and immediate feedback to students. This feedback includes the correct answer of each test item, and a 'more information' link to a further discussion of the question and related learning materials to the topic. TRIAD (http://www.derby.ac.uk/assess/newdemo/mainmenu.html) is a Web-based test equipped with functions of sign-on, question sequencing, results calculation and automatically filing. CyberExam (http://cyberexam.vlearning.com/) has a formative assessment module which allows the student to receive assessment reports immediately upon completing the test, and provides the student online help in areas of weakness.

Clearly the varieties of strategies outlined above are very important in the design of Web-based formative assessment. This research refers to studies made by Federico (2000), Kraus *et al*. (2001), Buchanan (1998) and Terrell (2002) when looking at improvement of the effectiveness of e-learning, and develops an e-learning environment that integrates formative assessment strategy. It then discusses what kind of learning style is appropriate for such e-learning design.

The purpose of this research is to discover whether the benefit of such e-learning environments varies among learners with different learning styles. Three questions are explored in this research. First, do learning styles and formative assessment strategy affect student-learning achievement? Second, what kind of formative assessment strategy can be built into the e-learning environment to facilitate student learning? Finally, what kind of learning style best suits the e-learning environment?

Methodology

Sample

Initially, participants 462 seventh-grade students from 12 classes of six junior high schools in five counties in central Taiwan. However, seven students were absent from classes during some instructional periods. Therefore, only data from the 455 students (221 females and 234 males) who actually received the treatment were analysed. Their gender, learning style, and distribution in each formative assessment strategy group is shown in Table 1. The majority of learners were Accommodator (33.2%). Only 14.2% students possessed diverger learning styles. Most subjects had taken courses relevant to computers in their elementary schools so that they had the fundamental ability to operate a computer and access the Internet. Before treatment, the subjects had experienced a pilot curriculum similar to the Web-based course used in this study.

Research design

The main purpose of this research was to assess impacts of formative assessment strategies and learning

Table 1. Numbers and percentages of students by gender, learning style, and formative assessment strategy.

Factor	Category	Number	Percentage
Gender	Male	221	48.6
	Female	234	51.4
Formative assessment strategy	FAM-WATA	157	34.5
	N-WATA	156	34.3
	PPT	142	31.2
Learning style	Diverger	66	14.5
	Accommodator	151	33.2
	Converger	122	26.8
	Assimilator	116	25.5

FAM-WATA, Formative Assessment Module of the Web-Based Assessment and Test Analysis System; N-WATA, Normal Module of the Web-Based Assessment and Test Analysis System; PPT, Paper and Pencil Test.

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Table 2. Strategies differences among FAM-WATA, N-WATA, and PPT groups.

Strategies Groups	Repeat the test	Provide with no answer	Ask questions	Query scores	Monitor answering history	All pass and then reward
FAM-WATA	O	O	O	O	O	O
N-WATA	≥ [1]	X	O	O	X	X
PPT	X	X	≥ [2]	≥ [3]	X	X

[1]partial strategies of 'repeat the test'.
[2,3]'Query scores' and 'Ask questions' strategies in a traditional classroom not through the Internet
FAM-WATA, Formative Assessment Module of the Web-Based Assessment and Test Analysis System; N-WATA, Normal Module of the Web-Based Assessment and Test Analysis System; PPT, Paper and Pencil Test.

style on Web-based learning. This research is a quasi-experimental research using the 'formative assessment model' and 'Kolb's learning style' as independent variables, and 'learning achievements' as the dependent variable. The participants, all seventh-grade students, were divided into Formative Assessment Module of the Web-Based Assessment and Test Analysis system (FAM-WATA), Normal Module of the Web-Based Assessment and Test Analysis system (N-WATA), and Paper and Pencil Test (PPT), groups, respectively, according to the different 'formative assessment model' they accepted. A comparison of the differences in each group's strategy design is shown in Table 2. Students in the FAM-WATA group were given an e-learning environment that combined all six major formative assessment strategies, but students receiving the N-WATA and PPT assessments experienced only some of the six strategies. All participants received the same e-learning course called BioCAL. These six formative strategies are discussed in the next section.

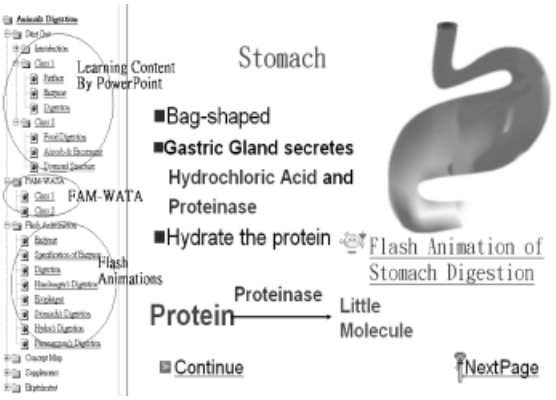

Fig 2 Frame structure of BioCAL: 'Digestion Unit'.

Learning material

This learning material for participants in this research, called BioCAL (as shown in Fig 2), is divided into two major areas: 'learning touring' and 'learning contents'. The 'learning touring' section uses a tree structure to present the entire course structure, a common design found in e-learning environments. The course structure is divided into six parts: 'Learning contents', 'Self-examination (Web-based formative assessment)', 'Concept maps', 'Flash animations', and 'Supplements'. The learning contents are displayed as PowerPoint presentations, reducing redundant text description as much as possible, and concentrating on the main points through diagrams and tables. Flash is applied to assist the e-learning.

The content related to this research is 'Digestion', a topic of the 'Nature Science and Life Technology' currently under study by seventh-grade students in junior high school in Taiwan. The mean instructional time needed to complete the unit was three class periods for e-learning approach and one class for assessment.

FAM-WATA

This module is built in the BioCAL for students' self-examination. The FAM-WATA is one module of the WATA system (Wang *et al*. 2004). The FAM-WATA provides teacher with six strategies for teachers while they use FAM-WATA as formative assessment on Web-based learning. These six strategies include 'repeat the test', 'provide with no answer', 'query scores', 'ask questions', 'monitor answering history' and 'all pass and then reward':

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(1) 'Repeat the test': This strategy allows students to take the same test item repeatedly if they make errors on it. However, if they pass one test item correctly three times continually, then the item will be deleted automatically.
(2) 'Provide with no answer': This strategy shows students incorrect answers they made without offering the correct answer. However, it also allows students leave the module to find correct answers in their own way.
(3) 'Ask questions': This strategy allows students send questions to the teacher by e-mail.
(4) 'Query scores': This strategy provides an interface for students to query peer and personal scores.
(5) 'Monitor answering history': This strategy provides an interface for students to check their personal answer history for each item.
(6) 'All pass and then reward': This strategy rewards students with a Flash animation when they pass all the test items.

Instruments

Kolb's LSI

Kolb's LSI was used as a self-assessment tool aimed at determining student learning style preferences (Kolb 1976, 1985, 1999). The instrument consist of 12 sentences that describe learning, each with four endings, that individuals rank based on which ending is most like or least like experience of themselves and in the order of 4, 3, 2, and 1, without repeating or skipping any. A '4' represents the highest level of similarly, in descending value to '1', the most dissimilar sentence. Participants must complete, in rank order, four sentence endings that correspond to four learning mode orientations: (1) CE, (2) AC, (3) AE, or (4) RO. The calculation process compiles all of the first endings of 12 statements to obtain the score of CE. Total scores of all of the second endings represent the score for RO. All of the third endings represent the AC score, while all of the fourth endings represent the AE score. Two learning style scores are derived from the four learning dimensions. The AC-CE score ('Preferred CE or AC' distinction) is calculated by subtracting the concrete experiencing value from the AC value. The AE–RO score is calculated from subtracting the RO value from the AE value. Two combinations of ranking scores are plotted on a grid to identify the intersection of the scores and thus indicate the preferred learning style quadrant of the learner: Diverger, Assimilator, Converger, or Accommodator (Kolb 2000).

According to Iliff (1994), the LSI is a valid tool for construct validation of ELT. In addition, Smith and Kolb (1986) report that the reliability for LSI version 2 ($N = 268$) are AC = 0.83, CE = 0.82, AE = 0.78, and RO = 0.73, respectively. To measure learner learning styles, this research uses a Chinese version of LSI, which was translated from LSI version 2 (Kolb 1985).

Learning achievement test

Two tests were developed in this research, the 'Formative Assessment', which is based on portions of the contents of the course, and the 'Summative Assessment' formulated as a whole based on the entire course. The test items in 'Formative Assessment' and 'Summative Assessment' are not repeated and this research uses the questions in 'Summative Assessment' as the pre- and post-test questions of the achievement test. Both 'Formative Assessment' and 'Summative Assessment' were offered to the 'FAM-WATA', 'N-WATA', and 'PPT' groups to evaluate learning effects. Both the formative and summative assessments were created on the WATA system (Wang *et al*. 2004), developed by the researchers.

The WATA system provides teachers with an easy way to edit the online achievement test according to pre-determined objectives and learning concepts. The WATA system is structured in accordance with the Triple-A Model (assembling, administering, and appraising) as the baseline qualification in order to provide the most comprehensive form of CBT or WBT (Wang *et al*. 2004). The WATA runs both formative assessment and summative assessment.

Formative assessments and summative assessments are administered differently. The summative assessment is administered as a traditional computer-based testing (CBT), which allows students to read test items on the computer screen, select answers with the mouse or keyboard, re-examine and revise them, and send them out, and then log out when they are finished. In other words, the computer simply acts as the medium for students to take exams, for teachers to construct tests, and for the transmission of test papers (Wang *et al*. 2004). However, the formative assessment in BioCAL is called FAM-WATA, which contains six

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Table 3. Sample items of Student Perception of FAM-WATA Scale.

Strategies	Items	SA	A	U	DA	SD
Repeat the test	It gives me more opportunities to familiar with learning materials	1	2	3	4	5
	It allows me to know what I need to study more	1	2	3	4	5
Provide with no answer	It pushes me to make clear what I didn't understand	1	2	3	4	5
	It gives me more opportunities to think questions actively	1	2	3	4	5
Ask questions	It gives me more opportunities to interact with my teacher	1	2	3	4	5
	It offers a more efficient way to clarify my incorrect concepts	1	2	3	4	5
Query scores	It helps me understand my grade status in class	1	2	3	4	5
	It helps me understand my classmate's grade status	1	2	3	4	5
Monitor answering history	It helps me understand my answer history	1	2	3	4	5
	It helps me understand what I have learned	1	2	3	4	5
All pass and then reward	It can arouse me to answer carefully in order to pass test	1	2	3	4	5
	It makes me have feeling of success if I pass test and get reward with flash screen, but my classmate don't	1	2	3	4	5

SA, strongly agree; A, agree; U, undecided; D, disagree; SD, strongly disagree; FAM-WATA, Formative Assessment Module of the Web-Based Assessment and Test Analysis System.

major strategies, including 'repeat the test', 'provide with no answer', 'query scores', 'ask questions', 'monitor answering history' and 'all pass and then reward.' These six strategies are designed based on the suggestions of Brown and Knight (1994), William and Black (1996), and Buchanan (2000), thus making FAM-WATA more effective.

The 'Summative Assessment' of the unit 'Digestion' consists of 20 test items on concepts related to the subject of digestion. A score of five-points is assigned to each test item. The average difficulty index of the 'Summative Assessment' is 0.50, with a KR20 of 0.92 (obtained from 342 valid samples).

WATA Formative Assessment Strategies Scale (WFASS)

WFASS was used to evaluate student attitudes toward the FAM-WATA. The WFASS was developed and revised by this research team. There are six subscales and 22 statements in the WFASS. Participants are asked to respond to the six strategies of the FAM-WATA (sample items are listed in Table 3). All subscales used a Likert five point scale, including 'strongly satisfied (5 points)', 'satisfied (4 points)', 'undecided (3 points)', 'unsatisfied (2 points)', and 'strongly unsatisfied (1 point).' If the average score of the items was over 3.0, we assume that the participants were satisfied with the strategies used in the FAM-WATA. The Cronbach' α of the entire scale is 0.88, and each subscale was over 0.70, including 'repeat the test': 0.74, 'provide with no answer': 0.74, 'query scores': 0.74, 'monitor answering history': 0.78, 'ask questions': 0.77, and 'all pass and then reward': 0.78.

Data collection and analysis

All data collected in this research come from the quantitative data from 'Kolb's LSI' and 'Summative Assessment' pre- and post-test scores. After data collection, the data were analyzed using SPSS PC 10.0 (Chinese Version). This research defined 'Summative assessment' pre-test achievements as the entry behaviour of learning, and post-test achievements as learning effects.

The data analysis divides learners into four styles based on Kolb's learning style: 'Diverger', 'Assimilator', 'Accommodator' and 'Converger'. The 'Formative Assessment Strategies' is the fixed factor, the pre-test of 'Summative Assessment' is the covariate, and post-test achievement is the dependent variable. One-way ANCOVA and LSD were carried out as a *post hoc* analysis to examine the effects of different formative assessment strategies on learners with four different learning styles.

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Table 4. Summary table of ANCOVA analysis of effects of formative strategies and learning styles on the achievement of subjects ($N = 455$).

Sources	SS	df	MS	F-value
PRE	40 378.89	1	40 378.89	174.06**
FA	1743.31	2	871.66	3.76*
LS	4741.80	3	1580.60	6.81**
FA × LS	799.70	6	133.28	0.58
Error	102 534.56	442	231.98	
Total	1 471 690.91	455		

*$P<0.05$, **$P<0.01$
PRE, pre-test score; FA, formative assessment strategies; LS, learning style.

Table 5. Mean score and standard error of learning style groups with different formative assessment strategies.

Factor	Group	Number	Mean*	Standard error
Formative assessment strategies	PPT	142	52.52	1.38
	N-WATA	156	53.21	1.24
	FAM-WATA	157	57.35	1.35
Learning Style	Diverger	66	57.55	1.95
	Accommodator	151	50.96	1.25
	Converger	122	51.01	1.41
	Assimilator	116	57.92	1.44

*Adjust with covariate: PRE (mean = 41.80).

Results

Learning styles and formative assessment strategies on student achievement of e-learning

Before using analysis of covariance to determine the effects of formative assessment strategies and learning styles on subject achievement in Web-based learning, Levine's method was used to test the homogeneity of variances. No significant difference in the variance of treatment groups ($F = 0.47$, $P > 0.05$) was found. In other words, the basic assumption of homogeneity of variance was not violated.

The results of ANCOVA are shown in Table 4. PRE (pre-test score) as a covariate had a significant influence on the POST (post-test score) of subjects ($F = 174.06$, $P < 0.01$). Furthermore, both Formative assessment strategy ($F = 3.76$, $P < 0.05$) and learning style ($F = 6.81$, $P < 0.01$) are significant factors in subject achievement. However, no significant interaction effects between formative assessment strategy and learning style on subject achievement ($F = 0.58$, $P > 0.05$) were found.

Comparisons of different formative assessment strategies on student achievement of e-learning

According to the previous analysis of ANCOVA, significant treatment effects were observed with formative assessment strategies. The post-achievement test mean score and standard error of each group are shown in Table 5. A *post hoc* analysis (LSD method) was performed for further comparison (see Table 6). It showed that the FAM-WATA group performed significantly better than the N-WATA group on achievement test mean score (mean difference = 4.14, $P = 0.03$) and the PPT group (mean difference = 4.83, $P = 0.01$). However, performance of the N-WATA group was no better than that of the PPT group (mean difference = 0.69, $P = 0.71$). In sum, *post hoc* analysis revealed that the FAM-WATA group performed better than the N-WATA group and the PPT group, and the performance of the N-WATA group was significantly better than that of the PPT group.

Comparisons of different learning styles on student achievement of e-learning

The post-achievement test mean score and standard error of each learning style group are also shown in Table 5. *Post hoc* analysis (LSD method) was also used to compare the performance of different learning styles (see Table 6). The mean score of Assimilator was highest, significantly greater than either Accommodator (mean difference = 6.96, $P = 0.00$) or Converger (mean difference = 6.91, $P = 0.00$). Diverger was also significantly greater than either Converger (mean difference = 6.54, $P = 0.01$) or Accommodator (mean difference = 6.59, $P = 0.01$). However, there was no significant difference between Diverger and Assimilator, and between Converger and Accommodator. In sum, Diverger and Assimilator (RO type) outperformed Converger and Accommodator (AE type) while Diverger performed no greater than Assimilator, and Converger performed as well as Accommodator.

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Table 6. *Post hoc* comparison (LSD method) for formative assessment strategies and learning style groups.

Factors	Comparisons	Mean difference	P-value*
Formative assessment strategies	FAM-WATA–N-WATA	4.14	0.03
	FAM-WATA–PPT	4.83	0.01
	N-WATA–PPT	0.69	0.71
Learning styles	Diverger–Accommodator	6.59	0.01
	Diverger–Converger	6.54	0.01
	Diverger–Assimilator	−0.37	0.88
	Assimilator–Accommodator	6.90	0.00
	Assimilator–Converger	6.91	0.00
	Converger–Accommodator	0.05	0.98

*Significant level with LSD method

FAM-WATA, Formative Assessment Module of the Web-Based Assessment and Test Analysis System; N-WATA, Normal Module of the Web-based Assessment and Test Analysis System; PPT, Paper and Pencil Test.

Table 7. Student perceptions of the FAM-WATA ($n = 157$).

Subscale	Items	Average	SD	Cronbach' α
Repeat the test	6	4.03	0.60	0.74
Provide with no answer	3	4.07	0.75	0.74
Query scores	4	3.88	0.74	0.74
Ask questions	3	4.20	0.66	0.77
Monitor answering history	3	3.96	0.78	0.78
All pass and then reward	3	4.18	0.69	0.78

FAM-WATA, Formative Assessment Module of the Web-Based Assessment and Test Analysis System.

Student perceptions of the FAM-WATA strategies

Student perceptions of the FAM-WATA were assessed by their response to the WFASS. An average score above 3.0 points represents satisfaction with the design.

Table 7 indicates that the average score of student perceptions for each subscale of the FAM-WATA are all above three points. The 'repeat the test' subscale is 4.03, 'provide with no answer' subscale is 4.07, 'ask questions' subscale is 3.88, 'query scores' subscale is 4.20, 'monitor answering history' subscale is 3.96, and 'all pass and then reward' subscale is 4.18. In sum, the participants show positive attitudes toward the six strategies in the FAM-WATA.

Conclusion and suggestions

This research used a multiple-choice Web-based formative assessment, FAM-WATA , and we augmented Buchanan's three strategies with three more new strategies in FAM-WATA, i.e. 'query scores', 'monitor answering history' and 'all pass and then reward'. In addition, this paper also presented a comparison of the learning achievement of learners with different learning styles in a Web-based learning environment in which three different types of formative assessment have been embedded.

The results indicated that both learning style and formative assessment strategy significantly affect student achievement in Web-based learning. This suggests that both formative assessment strategy and learning styles should be taken into account in the design of Web-based learning environments. This finding is consistent with previous research findings (Rasmussen & Davidson-Shivers 1998; Chou & Wang 2000; Federico 2000; Terrell 2002). However, this study did not find an interaction between these two factors. More research is needed to confirm this result.

In the present study, *post hoc* comparison showed that the performance of the FAM-WATA group is significantly higher than either the N-WATA or the

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PPT group. This finding suggests that the more diverse formative assessment strategies are embedded in the e-learning environment, the greater the learning effect obtained by the students. Recent research on teacher effectiveness has shown that successful teachers tend to be those who are able to use a range of teaching strategies and who use a range of interaction styles, rather than a single, rigid approach to teaching and learning (Darling-Hammond 2000). Although this research is implemented in a Web-based environment, the findings of our study confirm this understanding.

The study found that performances of different learning styles range from the highest, 'Assimilator', descending through 'Diverger' and 'Accommodator', to the lowest, 'Converger'. Clearly RO type learners (Diverger and Assimilator) outperformed AE type learners (Accommodator and Converger) in the course design of this study. This finding is inconsistent with the findings of learning style studies that have found AC type learners (Converger and Assimilator) perform better than CE styles (Rasmussen & Davidson-Shivers 1998; Federico 2000; Terrell 2002). The explanation for our findings may lie in the design of the environment. According to Kolb (1984), learning style differences vary with differences in the learning environment. One possible factor may be that our e-learning environment, BioCAL, provided learners with more opportunities to perceive information rather than process information. The learning material is highly structural and multimedia with pictures and animations that may be more beneficial for RO type students than AE types. However, more investigation is necessary.

The findings of this research have important implications for e-learning design of junior high school science courses, as well as for research into the benefits of e-learning. First, awareness of student learning styles may be helpful in e-learning design and for increasing student performance in Web-based learning environments. In addition, future research into e-learning should take into account learning style as an important variable so that the research can be more complete.

Second, given that students have diverse backgrounds, abilities, and knowledge bases, teachers who are able to use various instructional strategies have been shown to be more effective than those who just use single teaching strategies (Darling-Hammond 2000). This study lends support to the following: the more diverse the Web-based formative assessment strategies, the greater the learning effect obtained by the students.

Based on our findings, it seems obvious that the development of e-learning strategy designs for different learning styles may be enhanced by providing educational technology creators with access to information and training in the widest possible range of teaching techniques.

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