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What affect student cognitive style in the development of hypermedia learning system?

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Abstract

Recent developments in learning technology such as hypermedia is becoming widespread and offer significant contribution to improve the delivery of learning and teaching materials. A key factor in the development of hypermedia learning system is cognitive style (CS) as it relates to users' information processing habits, representing individual user's typical modes of perceiving, thinking, remembering and problem solving. The sample comprised of 217 students from Murdoch University who were enrolled in a first-year undergraduate unit. A survey was carried out every second semester over a period of 3 years (1999–2001). Both generalized linear model and tree-based regression were used to analyse the interaction among the learning dimensions and the effect on students' CS. When comparing both models, tree-based regression outperformed generalized linear model in this study. The research findings indicated that non-linear learning is the primary dimension that determines students' CS. This is subsequently, followed by multiple tools (MT) and learner control (LC) dimensions. The results also confirm that background information has effects on students' CS. The overall findings suggest that students' preference of learning dimensions such as linear vs. non-linear, level of LC and the range of MT must be taken into consideration in order to enrich students' quality of education by means of motivating students' acquisition of subject matter through individualize instruction when designing, developing, and delivering educational resources.

Keywords: Cognitive style; Hypermedia learning system; Generalized linear model; Tree-based regression

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1. Introduction

Recent developments in the learning technology such as hypermedia is becoming widespread and offer significant contribution to improve the delivery of learning and teaching materials. A key factor in the development of hypermedia-based learning is cognitive style (CS) as it relates to users' information processing habits, representing individual user's typical modes of perceiving, thinking, remembering and problem solving. Earlier research (Andris, 1996; Chen & Ford, 1998; Chen & Macredie, 2002; Durfresne & Turcotte, 1997; Ford & Chen, 2000; Liu & Reed, 1994; Palmquist & Kim, 2000; Reed & Oughton, 1997; Saracho, 1998; Wang, Hawk, & Tenopir, 2000) revealed that learning dimensions (characteristics and learning patterns) such as non-linear learning (NL), learner control (LC) and multiple tools (MT) have significant effect on students' CS (either field dependent or field independent individuals) in a hypermedia learning system. Thus, this research focuses on:

(i) exploring the correlation between the three learning dimensions;
(ii) investigating the interaction among the three learning dimensions and their effect on students' CS using two different methods of analysis, namely generalized linear model and tree-based regression; and
(iii) comparing the effect of students' background and the three learning dimensions on students' CS.

2. Literature framework

Many assumed that students in general, learn the same things in the same ways and at the same rate. However, not all types of students are capable of developing their learning paths by themselves. This leads to some variation in what students can acquire out of a learning process. A number of studies have established clear links between different learning environments and the adopted approaches to learning (Entwistle & Entwistle, 1992; Maguire, Evans, & Dyas, 2001). In responding to such differences among individual students, teachers had continuously attempted to use alternative teaching techniques and modified educational settings in order to enrich the quality of education for students. Recently, educational environments employing hypermedia in Web-based education have been used as an innovative means for structuring and presenting online instruction since such enhanced environments can simultaneously serve as delivery medium, content provider and subject matter. Researchers have assumed that students' different CS have the tendency to influence their learning (Saracho, 1998). Hence, it is assumed here that students' CS have the tendency to facilitate or interfere with the interacting and learning from an innovative environment such as a hypermedia learning system. Therefore, it is anticipated that through assessing the interaction of learning dimensions and its effect on students' CS, a deeper understanding and awareness of students' particular preferences will be obtained. This can then be used to improve the planning, production and implementation of educational experiences that are more compatible with students' learning preferences, in order to enhance their learning, retention and retrieval of information.

2.1. Hypermedia

"Hypermedia refers to online settings where networks of multimedia nodes connected by links are used to present information and manage retrieval" (Federico, 2000). Multimedia nodes may include texts, graphics, videos, audios, animations, models, simulations, and visualisations that can be accessed and viewed by interactive browsers such as Microsoft's Internet Explorer. It also enables quick access to a large amount of information under such multiple formats. Often, the connectivity among these nodes is constrained by the design of the specific network-based educational environment. Nevertheless, a student ultimately determines the navigational paths through the nodes, by freely controlling the movement among nodes, according to intrinsic interests and present goals (Federico, 2000; Stanton, Correia, & Dias, 2000).

2.2. Cognitive style

CS is one of the commonly researched measures of learner differences (Oughton & Reed, 1999). It represents an individual's psychological differentiation that determines the individuals' responses and functioning in numerous situations that includes stable attitudes, choices, and habitual strategies related to an individual's style of perceiving, remembering, thinking and solving problems (Saracho, 1998). A widely cited definition based on Messick's (1984) defined cognitive style as individual differences in preferred ways of organising and processing information and experience (Chen & Macredie, 2002; Sadler-Smith, 2001; Triantafillou, Pomportsis, & Demetriadis, 2003).

CS can be classified as either field dependent (FD) or field independent (FI). FD individuals prefer to be guided in their learning processes, employ less analytic approaches to learning (require more instructional guidance to assist them to find out relevant and meaningful information to reduce disorientation) (Chou, 2001; Oughton & Reed, 1999; Tinajero & Paramo, 1998). On the other hand, FI individuals employ less guided but more analytical and autonomy approach to learning (Chou, 2001; Oughton & Reed, 1999; Tinajero & Paramo, 1998). Details of the characteristics of FD and FI learners are summarised in Table 1.

Table 1
FD and FI categories

Field dependent learners	Field independent learners
More likely to face difficulties in restructuring new information and forging links with prior knowledge	Able to reorganise information to provide a context for prior knowledge
Their personalities show a greater social orientation	They are influenced less by social reinforcement
Experience surroundings in a relatively global fashion, passively conforming to the influence of the prevailing field or context	Experience surroundings analytically, with objects experienced as being discrete from their backgrounds
Demonstrate fewer proportional reasoning skills	Demonstrate greater proportional reasoning skills
Prefer working in groups	Prefer working alone
Struggle with individual elements	Good with problems that require taking elements out of their whole context
Externally directed	Internally directed
Influenced by salient features	Individualistic
Accept ideas as presented	Accept ideas strengthened through analysis

Source, Chen and Macredie (2002).

One of the most widely studied cognitive styles with the broadest application to the problems of education is Witkin's Field Dependence (Chou, 2001; Liu & Reed, 1994; Tinajero & Paramo, 1998; Weller, Repman, & Rooze, 1994). Witkin's studies were aimed at distinguishing how well a learner is able to restructure information based on the use of salient cues and field arrangement. Such studies revealed that individuals are different but individually consistent in their preferred modes of processing information (Witkin, 1950; Witkin & Asch, 1948; Witkin & Moore, 1974).

Recent studies on CS suggested that students who are FD succeed best with socially oriented learning tasks, e.g., cooperative learning style whilst FI students rather work on abstract and less socially oriented assignments (Saracho, 1998). Several studies, which examined matching instructional strategies with levels of field dependence, have indicated that learning in matched conditions may in certain contexts be significantly more effective than learning in mismatched conditions. Witten's (1989) investigation found that FD students performed at essentially equivalent levels as FI students in a congruent teaching method. In contrast, FD students were adversely affected when taught with an incongruent method. A similar result was reported by Ford (1995), which stressed that learning in the matched conditions was significantly superior to that in the mismatched conditions.

Furthermore, an empirical study made by Ford and Chen (2001) revealed that students in conditions matched with their CS performed better in the post-test and obtained better gain scores. Fullerton (2000) discovered that FD learners scored lower than FI learners in a condition mismatched with their preferred manipulation. The research outcome conducted by Lee (2000) showed that FI learners tended to be internally driven in contrast to FD learners who rely on the external forces to perform a task. On the other hand, FD learners' performance deteriorated when received an instructional strategy that contradicted with their CS. FD individuals could outperform FI individuals when the preferences of their CS are matched. Therefore, matching the style of teaching to suit students' CS is essential with regard to learning effectiveness.

3. Research model and hypothesis

The research model was adapted from Chen and Macredie (2002) as it classifies previous studies and presents the effects of CS on hypermedia learning and the relationship between key areas (NL, LC and MT). This learning model forms a bridge between CS and hypermedia learning that can be applied for the design of adaptive hypermedia systems to tailored and match with particular preferences of FD and FD students. Furthermore, this research is further enhance with the integration of a quantitative aspect in verifying Chen and Macredie's learning model, given that they took a qualitative approach in presenting the effects of CS on hypermedia learning.

3.1. Non-linear learning approach

Individuals, who prefer a linear learning approach, are considered as FD individuals. Such individuals generally demonstrate greater social orientation that means that they enjoy working in groups. Furthermore, they are more likely to face difficulties in an unstructured environment or when they have to restructure new information and forge links with prior knowledge because they demonstrate fewer proportioning skills (Biggs & Telfer, 1987; Chen & Macredie, 2002; Chou,

2001). In other words, they prefer guided navigation or linear format representation and tend to demonstrate more syllabus-boundness characteristics. These individuals also fear failure but focus on a bare minimum pass as they often show less interest in the course content. In addition, they show heavy reliance on the use of their memory as well as strongly depend on external references such as their course tutors who dictate the information to be learnt. These are often due to their lack of understanding of the purpose and objectives of the course (Biggs & Telfer, 1987; Chen & Macredie, 2002; Chou, 2001). In contrast, individuals who adopt a NL approach are categorised as FI individuals. They are characterised as individuals who enjoy working alone and prefer free navigation or the use of discovery approach to explore the topic of interest as well as to generate ideas. They tend to seek meaning in order to understand the course content. In addition, they will attempt to relate ideas between courses as well as the use of evidence when making conclusions (Biggs & Telfer, 1987; Chen & Macredie, 2002; Chou, 2001).

3.2. Learner control

LC is the degree to which individuals control their own learning experience (Lin & Hsieh, 2001). There has been an increasing importance of learning dimension such as LC, as it is assumed that students will be more motivated to learn if allowed to control their own learning (Lin & Hsieh, 2001). FD individuals perform better with the program control version of computer-based instruction, as they are relatively passive and less capable of learning independently (externally directed; require guidance). These individuals can be characterised as using less control features in hypermedia programs. On the other hand, FI individuals use greater control features in hypermedia programs, as they possess higher ability to engage in independent learning (internally directed) with analytical thought and perform better in the LC version of computer-based instruction (Chen & Macredie, 2002; Yoon, 1994). Hence, FI individuals are likely to perform significantly better and learn more effectively than FD individuals in a hypermedia learning environment. This is because FI individuals can make their own decisions to meet their own needs at their own pace and in accordance with their existing knowledge and learning goals, whilst skipping material they already know and concentrate on the material they deem relevant (Lin & Hsieh, 2001).

3.3. Multiple tools

The different approaches demonstrated by individuals when using MT are associated with identifying the differences between FD and FI individuals. FD individuals process information in a global fashion (accept ideas as presented), and rely on maps to build the entire perceptual field or context. Conversely, FI individuals tend to analytically approach a problem and task oriented where index and other tools are highly used by them to find specific information in a hypermedia system (Chen & Macredie, 2002). A hypermedia environment is usually designed using non-linear multidimensional paths traversing the subject matter to provide multiple perspectives of the content, in order to guide student acquisition of the subject matter. Generally, individual learners are able to control their own paths through complex subject matter independently of the guidance provided by the course tutor. However, learners can quickly and easily get lost or become disoriented in cyberspace given a hypermedia environment's complexity, such as too many links and

MT available (Stanton et al., 2000). In such a situation, FD individuals tend to desire greater navigation support in contrast to FI individuals since FD individuals tend to get confused more easily on the web (Chen & Macredie, 2002). In other words, FD individuals are less likely to utilise all the tools provided in comparison to FI individuals as they feel uncomfortable using the tools provided to navigate the web or when carrying out an assigned task without being assisted. As a result, FD individuals tend to express difficulty in learning and are less likely to value their overall learning experience.

3.4. Hypothesis

H_A: All students' learning dimensions are positively correlated.
H_B: Higher order interactions among students' learning dimensions affect their CS.
H_C: Students' background information affects their CS.

4. Methodology

4.1. Course background

The unit that was examined is a first-year Information Technology course dealing with fundamentals of multimedia and its delivery on the Internet and the World Wide Web. The unit introduces students to multimedia as a combination of text, graphics, video, animation and sound for the purposes of information access, storage and dissemination. Topics include the nature of multimedia and types of multimedia objects, components of a multimedia system, Web authoring, multimedia delivery tools, multimedia applications and societal implications of multimedia. Students also learn to create multimedia applications using HTML. JavaScript, animation, sound and video. The course was structured in a less extensive use of a hypermedia system that comprised of the use of WebCT, an online teaching management package and traditional regular lecture (2 h per week) as well as tutorial format (1 h per week). WebCT is a course management tool that provides the instructor and students with many capabilities such as posting documents such as lecture notes in HTML and other formats that can be easily downloaded. WebCT also facilitates interchange between students and instructor with the use of email and bulletin boards. Using WebCT, students can navigate independently and get to explore a subject matter at their own pace, giving them greater control over what they read and the order in which they read it. This course makes it particularly suitable for comparing and assessing students' perception of the current lecture-based offering with a WWW-based offering.

4.2. Sample

The sample comprised of 217 (86 + 79 + 52) students who were enrolled in an undergraduate course, based on cluster sampling and was carried out in second semester over a period of 3 years (1999–2001) at Murdoch University, Western Australia. 60% of the respondents were male students while 40% were female students. The percentage of complete information in the 3 years surveys varied from 93% to 97%. Using two samples binomial test, there was no

difference ($0.1 < P < 0.9$) in the response variable between any of the 2 years surveys. The 3 years data sets were combined together for further analysis in order to increase the power of statistical test and the possibility of studying higher order interaction among the predictor variables.

4.3. Evaluation tools

The questionnaire was designed based on the theoretical framework adapted from Chen and Macredie (2002) characteristics and learning patterns of FD and FI individuals and it was also partially taken from Entwistle and Entwistle (1992) approaches to learning.

CS measure (question 1): the questionnaire identifies an individual's position of either one of the two categories of CS – the FD or FI. There are three learning dimensions that determine a student's CS, namely non-linear learning approach (NL) (open/distance/flexible learning and computer-assisted learning) or linear learning approach (tutorial and lecture); greater level of LC or least level of LC over learning environment; and minimum maximum MT usage in a hypermedia learning system. The teaching and learning methods (learning dimensions) to which participants had been exposed during the normal course of their studies determine their category of CS. The respondents were required to answer the questions listed in the questionnaire. Correspondingly, CS measure was determined as the response variable and the learning dimensions were determined as the predictor variable. The survey responses were scaled according to the sum of all questions score and dividing by total number of questions. The division gives a scale of 0 or 1, for example, 0 represents linear learning approach and 1 represents NL approach. There are 15 questions that are related to NL, 8 questions related to LC and 25 questions related to MT. A high score on the linear learning approach suggests that the individuals tend to employ less analytic approach to learning which subsequently falls into the category of FD individuals and vice versa. A greater score of low level LC indicates that the individuals prefer to be guided in their learning process, thus are categorised as FD individuals. All the questions are listed in Appendix A.

In addition, there are several questions related to their background, which include age (A) (nine levels – 17–20, 21–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, above 56), gender (G) (two levels – male, female), major (M) (two levels – computer study, others), do you have children? (C) (two levels – yes, no), enrollment (Y) (three levels – 1999–2001) and lecture attendance (T) (four levels – 100%, 75%, 50%, <50%).

4.4. Tools for statistical analysis

The binomial test was used to compare the mean of two groups that primarily consist of binomial outcomes. On the other hand, correlation was used to describe the relationship between two groups of variables. Pearson's product moment correlation coefficient was used to determine if the correlation is either equal or not equal to zero by using the 5% significant level of committing a Type I error. Statistical modelling was carried out using both parametric and non-parameteric models, namely the generalized linear model and tree-based regression. The response variable, CS, is a binary response; so the generalized linear model (McCullagh & Nelder, 1989) with logit link (binomial family) was used instead of multiple linear regression. This was to

ensure that the prediction would not be greater than one or less than zero. Both Akaike Information Criteria (AIC) (Akaike, 1974) and Bayesian Information Criteria (BIC) (Schwarz, 1978) were used to select the best subset of predictor variables within the generalized linear model. The predictor variables consist of the three learning dimensions and background information of students. A total of 5184 observations were required in order to investigate all combinations of the interaction among these predictor variables. However, we only had a total of 217 observations and therefore, had to assume there are higher order interactions between the three learning dimensions but no interaction between all learning dimensions and students' background information, as well as no interaction among students' background information when conducting statistical analysis using the generalized linear model. Tree-based regression was also used to study the effect of higher order interaction of the predictor variables on the response variable. The automatic construction of a decision tree was first used in the social sciences field by Morgan and Sonquist (1963). Tree-based method (Breiman, Friedman, Olshen, & Stone, 1984) is an alternative means to generalized linear (Watters & Deriso, 2000) and additive models for regression problems and to linear logistic and additive logistic models for classification problems. This model is also best suited to carry out statistical analysis on limited data. These types of models are fitted by binary recursive partitioning of a dataset into increasingly homogeneous subsets until it is infeasible to continue. Their use has been increasingly widespread in other fields such as social science (Morgan & Sonquist, 1963), statistics (Breiman et al., 1984) and machine learning (Quinlan, 1979, 1983, 1986, 1993).

5. Results and discussion

5.1. Correlation between the three learning dimensions

Table 2 shows no significant negative correlation between all the learning dimensions. MT and LC have the highest correlation 0.30 ($P < 0.000$), followed by NL and LC with significant correlation of 0.14 ($P < 0.041$). On the other hand, MT has marginal significant correlation 0.13 ($P = 0.052 < 0.10$) with NL. Although the correlations are significant but it is important to note that none of the correlations are greater than 0.5. Therefore, it is unlikely that there is a possible replication of measures among the three learning dimensions that are positively correlated.

In Table 3, all learning dimensions' mean are close to 0.5 except NL. If the value of learning dimensions falls in the first quartile, then it represents linear learner, or low LC or low MT usage. If the value of learning dimensions falls in the third quartile, then it represents non-linear learner, or high LC or frequent use of MT (see Fig. 1).

Table 2
Correlation between the three learning dimensions from the survey results of students. () is the *P*-value of type I error

Correlation	NL	LC
MT	0.14 ($P = 0.052$)	0.30 ($P = 0.000$)
LC	0.13 ($P = 0.041$)	

Table 3
Summary the distributions of three learning dimensions

Learning dimension	Minimum	1st Quartile	Medium	3rd Quartile	Maximum	Mean
NL	0.20	0.60	0.67	0.80	1.0	0.68
LC	0.13	0.38	0.5	0.63	1.0	0.54
MT	0.00	0.36	0.48	0.64	0.96	0.49

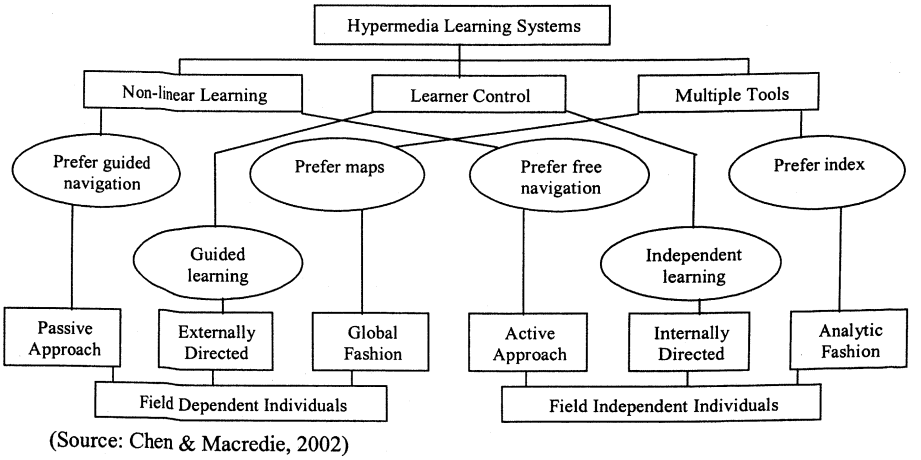

Fig. 1. Characteristics and learning patterns of FD and FI Individuals.

5.2. Relationship between CS and the three learning dimensions

Results generated by generalized linear model with logit link (binomial family) indicated that only NL is significant ($P < 0.00$) on CS. Other predictor variables and the higher order interaction among the predictor variables show no significant results ($P > 0.10$). The residual mean deviance is 1.317.

On the other hand, results generated by tree-based regression are illustrated in Fig. 2. All (NL, MT and LC) three predictor variables are used to construct the tree. The residual mean deviance is 1.216 with number of terminal nodes equal to 11. The first split on the left side of the tree-based regression indicates that students with linear learning approach ($NL < 0.37$) are classified as FD students. On the other hand, students that adopted NL approach ($NL \geqslant 0.79$) are classified as FI students. However, the subsequent split of the tree-regression showed that students with median NL approach ($0.37 \leqslant NL < 0.79$) and had used relatively low MT ($MT < 0.34$) are classified as FD students. In addition, students who adopted median NL approach ($0.37 \leqslant NL < 0.79$) and used substantial greater MT ($MT \geqslant 0.62$) are indicated as FI students. Further split, demonstrated that students with NL approach within the median range of ($0.37 \leqslant NL < 0.52$) and had rather moderate use of MT with ($0.34 \leqslant MT < 0.62$) are FI students. However, students with NL approach within higher median range where ($0.52 \leqslant NL < 0.79$) and moderate use of MT of ($0.34 \leqslant MT < 0.62$) as well as relatively low LC ($LC < 0.4$) are FD students. Students with NL approach within ($0.52 \leqslant NL < 0.79$) and had low use of MT ($0.34 \leqslant MT < 0.38$) along with greater level of LC ($LC \geqslant 0.4$) are FD students. Further splits indicated that students with NL

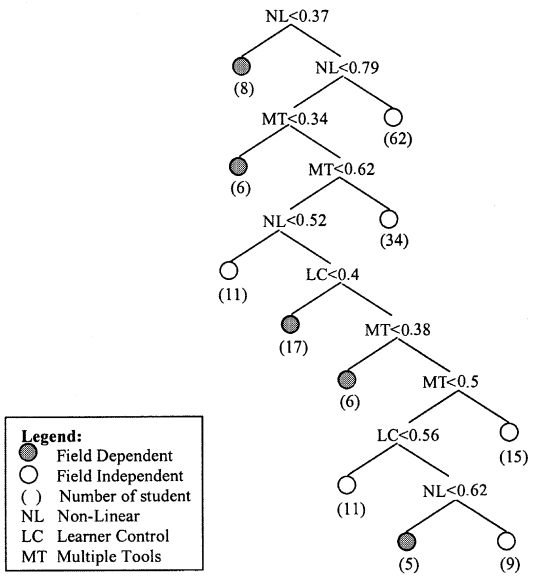

Fig. 2. Summary of tree-based regression result with response variable CS and the predictor variables of NL, LC and MT (residual mean deviance = 1.216, number terminal nodes = 11).

approach within ($0.52 \leqslant \mathrm{NL} < 0.79$) and had moderately high use of MT in the range where ($0.38 \leqslant \mathrm{MT} < 0.5$) along with relatively high LC ($\mathrm{LC} \geqslant 0.4$) are FI students. Whilst students with NL approach within ($0.52 \leqslant \mathrm{NL} < 0.79$) and had moderately low use of MT where ($0.38 \leqslant \mathrm{MT} < 0.5$) as well as LC ($0.4 \leqslant \mathrm{LC} < 0.56$) are FI students. Subsequently, students with NL approach within relatively high median range of ($0.52 \leqslant \mathrm{NL} < 0.62$) and had moderately low MT usage where ($0.38 \leqslant \mathrm{MT} < 0.5$) as well as greater LC where ($\mathrm{LC} \geqslant 0.56$) are FD students. The final split presented in the tree-regression revealed that students with NL approach within ($0.62 \leqslant \mathrm{NL} < 0.79$) and MT of ($0.38 \leqslant \mathrm{MT} < 0.5$) and LC ($\mathrm{LC} \geqslant 0.56$) are FI students.

The findings of this research give details of the interaction among the three learning dimensions and the effect on students' CS. Table 4 shows a summary of previous studies that support the findings of this research. A major highlight is that NL approach is a primary dimension in determining students' CS in a hypermedia learning environment. This is then followed by other factors namely MT and LC. Also, the type of learning dimensions adopted provides a significant determination of a student's CS. This means that students' CS is a key factor in the development of hypermedia learning system since students' differences (either FD or FI) are evident in a hypermedia-based learning environment.

5.3. Relationship among CS, learning dimensions and students' background information

Using generalized linear model with logit link (binomial family), the predictor variables such as year of enrollment (Y) and attendance frequency (T) are significant ($P < 0.05$) on CS in the final model based on the selection made according to both AIC and BIC criteria. The predictor variables such as gender (G), MT and LC had only marginal significance ($0.05 < P < 0.1$) on CS.

Table 4
Summary of tree-based regression with the three learning dimensions, and previous research results

Predictor variable	Tree-based regression results	Previous research results
NL	FD students are generally accustomed to a linear learning ($NL < 0.37$) structure (traditional mode of learning) in contrast to FI students' preference for non-linear learning ($NL \geqslant 0.79$) approach	FD students generally took more linear steps than FI students (FI students prefer less linear learning approach in contrast to FD students) (Andris, 1996; Reed & Oughton, 1997) FD students tend to spend more time completing the test in a free access version (non-linear) of hypermedia systems in contrast to the restricted version (Durfresne & Turcotte, 1997) Experienced FD subjects' performance was less than that of experienced FI subjects, especially when explicit structure was not provided (Korthaure & Koubek, 1994)
MT	Students with median non-linear learning approach ($0.37 \leqslant NL < 0.79$) and a low multiple tools ($ML < 0.34$) score can be categorised as FD students	Students with strong FD have the tendency of getting confused more easily on the web than those with strong FI (Wang et al., 2000) FD students preferred a well-structured format, especially for those with little or no experience in online searching (Palmquist & Kim, 2000) FI students thought the structure of the hypermedia system was clear whilst FD students experienced more disorientation problems (Chen & Ford, 1998) FD students used few new terms, but they retrieved many relevant references whilst FI students used many new terms but obtained less relevant references (Wood, Ford, Miller, Sobczyk, & Duffin, 1996) Students' CS are influenced by their navigation strategies. For instance, FD students tended to follow the sequence provided by the program, whereas, FI students tended to jump freely from one point to another using the index tool (Liu & Reed, 1995)
LC	LC has showed less significance in determining students' CS. (LC is inconsistent with the concept of determining students' CS)	FD and FI students performed equally well but they demonstrated different navigation patterns (Ford & Chen, 2000) FD and FI students used the program for an equivalent amount of time (Fitzgerald, 1998) Although FD and FI students' learning performance were equally good, these students chose different types of media, tools and learning aids (Liu & Reed, 1995)

The predictor variables and other higher order interaction between or among the three learning dimensions are not significant ($0.1 < P < 0.2$). The residual mean deviance is 1.284.

Based on the tree-based regression analysis, the three learning dimensions (NL, MT, LC) and students' background information (A, C, G, M, T, Y) have been used to construct the tree. The residual mean deviance is 1.165 and the number of terminal nodes is 8. The first split on the left side of the tree-based regression indicates that students with linear learning approach ($NL < 0.62$) are FD students. Whilst further split on the right side of the tree-regression showed that students with non-linear learning approach ($NL \geqslant 0.62$) and their age between 21 and 45 years are FI students. In contrast, students with non-linear learning approach ($NL \geqslant 0.62$) and were 17–21 and over 45 years of age and above along with less learning control ($LC < 0.31$) are FD students. Moreover, further splits on the tree-regression indicated that female students with greater learning control ($LC \geqslant 0.31$) and were enrolled in the year 2001 are FI students in contrast: to female students who were enrolled in the year 1999 and 2000. On the other hand, male students who had used substantially greater multiple tools ($MT \geqslant 0.38$) are FI students. The remaining split indicated that male students who used less multiple tools ($MT < 0.38$) and had attended less than 50% lectures are FD students while male students who had attended greater than 50% lectures are FI students.

Several previous studies that support the findings of comparing the effect of students' background and the three learning dimensions on students' CS are summarized in Table 5. Students' background information was introduced in this study because it may contribute to the understanding of important elements of background information that have substantial effects on students' CS. A trend has been anecdotally noted that students enrolling in later years have a greater exposure to online tools prior to enrollment. This suggests that there is a possibility that female students who are FI tend to be more experienced compare to the FD female students.

Apparently the result in Fig. 3 demonstrated that students' background information plays an important role in determining the response result in contrast to the result shown in Fig. 2. Nevertheless, it is obvious that NL approach proves to be the primary role in determining the CS in contrast to background information. Hence, it can be suggested here that LC, MT vary with students' background information and have higher order interaction of the response. This clearly shows that previous research has not taken into account the importance of students' background information. Thus, some findings resulted with significant or non-significant effects of LC with CS as the effect of LC varies with the background information in determining CS (Chen & Macredie, 2002).

Comparing the residual mean deviance and the number of terminal nodes (Figs. 2 and 3) from the two tree-based regression fits, the latter fit has smaller residual mean deviance and less number of nodes. This indicates the latter fit is better than the first one. The background information is an important component in explaining CS – especially the age of the students.

Clearly tree-based regression outperformed generalized linear model based on the comparison made in this study. The mean residual deviances fitted by generalized linear model in both analyses (Sections 5.2 and 5.3) were greater than the mean residual deviance fitted by tree-based regressions. This means that the tree-based regression resulted with better fits compared with the generalized linear model. The results based on generalized linear model are very difficult to interpret and could not further explain the interactions of all variables given the limited data. Tree-based models are easier to interpret and discuss in contrast to generalized linear models when

Table 5
Summary of tree-based regression result with the three learning dimensions, students' background information, and previous research results

Predictor variable	Tree-based regression results	Previous research results
LC	LC plays a vital role in determining students' CS when they prefer non-linear learning approach (NL $\geqslant$ 0.62) and their ages are either over 45 or under 21	FI students significantly obtained higher scores than FD students in a hypermedia learning system that taught students the components of computer systems (Umar, 1999) FI students learned more effectively than FD students as they found that FD students answered fewer questions and accessed slightly more concepts explanations within a computer software stack (Weller et al., 1994) FI students have the ability to engage in independent learning, perform better in the learner control environments in contrast to FD students who are rather passive and less capable to learn independently, performed better with the program control (Yoon, 1994)
Background information	A variable that has primary impact on students' CS with high nonlinear learning approach (NL $\geqslant$ 0.62) in hypermedia environment is age. Those between 21 and 45 years of age were FI students in contrast to students within the age range of 17–21 or greater than 45 years were FD students	Marchionini (1989) found that among elementary school students, older ones retrieved information on an online information system more efficiently than the younger ones
	Gender has effects on students' CS, particularly students under the age of 21 and over 45 and has preference for nonlinear learning approach (NL $\geqslant$ 0.62) and high learner control (LC $\geqslant$ 0.31)	Gender significantly moderates the effects of cognitive style and training method on learning performance and computer self-efficacy (Chou, 2001) Students' gender differences and levels of prior experiences had effects on their learning outcome in a hypermedia environment with learner control features (Chen, 1991)
	A trend has been anecdotally noted that students enrolling in later years have a greater exposure to online tools prior to enrollment. This suggests that there is a possibility that female students who are FI tend to be more experienced compare to the FD female students.	Investigating the effects of user variables (e.g., age, gender, academic background, computer experience, web experience) on information seeking behaviour on the web. Among those who had little experience or no experience with online search, FI individuals tended to outperform FD individuals (Kim, 2000, 2001) Participants with more hypermedia experience had greater non-linear steps than those with less hypermedia experience and vice versa (Reed, Oughton, Ayersman, Ervin, & Giessler, 2000)

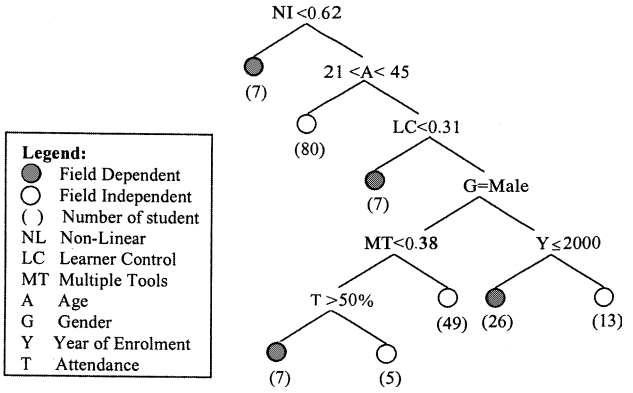

Fig. 3. Summary of tree-based regression result with response variable CS. The predictor variables are the three learning dimensions and students' background information (residual mean deviance = 1.166, number terminal nodes = 8).

analysing a set of independent variables that contain a mixture of numeric variables and factors. They do not predict or grow nodes when there are insufficient data and they are robust to monotonic behaviour of independent variables, so that the precise form in which these appear in the model is irrelevant. The standard linear model does not allow interactions between independent variables unless they are in multiplicative form. Tree-based models can detect interaction between parts of levels or parts of the numeric range of independent variables. Thus, the tree-based regression method is mainly employed to analyse the relationship among CS, learning dimensions and background information.

6. Conclusion

The overall findings suggest that student CS is a key factor in the development of hypermedia learning system since different types of learning dimensions are evident and must be taken into considerations in order to enrich the quality of education for students. This is essential in order to achieve a level of teaching effectiveness that could accommodate the learning; needs of different learners. Additionally, this research supports the idea made by previous researches such as Liu and Reed (1994), Papanikolaou, Grigoriadou, Magoulas, and Kornilakis (2002), Rada (1991) and Triantafillou et al. (2003), which emphasised the importance of having different perspectives of hypermedia design for potential matching with various learner characteristics and preferences, which would possibly result in higher quality of learning. Moreover, the learning model adapted from Chen and Macredie (2002) had essentially confirmed its effectiveness in illustrating the effects of CS on hypermedia systems. This indicates that such a model can be applied to the design of adaptive hypermedia systems that can be tailored to individualize instruction.

The results derived from this research may not apply in other countries and must be treated with a certain degree of caution as CS may vary with different culture. It would be interesting to assess CS on the basis of Hofstede's Dimensions of Cultural Differences framework (Hofstede, 1993). Additionally, cluster sampling may lead to a bias result. Ideally, this research should have

Table 6

CS	Describe your approach to study for a unit?
FD	Reproduce content from lecture notes without developing any clear structure of your own, reproduce the content within the structure used by the lecturer.
FI	Develops own structure, but solely to generate answers to anticipated exam questions, adjust structures from strategic reading to represent personal understanding, but also to control examination requirements, develops an individual conception of the discipline from wide reading and reflection.

NL	Response
Do you prefer to work on an assignment or project that contained open-ended questions where you have to explore the boundaries of the question and the topic?	Yes/No
Do you work on a practical exercise because you want to learn more?	Yes/No
To keep up with the unit should there be weekly exercises, which are assessed?	Yes/No
Have you completed more than half of the self-paced HTML tutorial, so far?	Yes/No
Do you always read the online notes?	Yes/No
Do you access the course guide very often?	Yes/No
Do you prefer to look for your own textbook or other reference books given a list of topics?	Yes/No
Do you believe that adult learners are better suited to independent learning?	Yes/No
Do you believe that access to a course guide is necessary?	Yes/No
Do you read all of the topic readings before attending a tutorial?	Yes/No
Do you think that the tutorial information and readings should be available online?	Yes/No
Do you agree that the readings and workload for this unit suitable?	Yes/No
Do you agree that the unit have the structure that suited to your learning style?	Yes/No
Was it clear to you what you are expected to learn (objectives) in this unit based on the study guide and unit outlines provided?	Yes/No
Do you prefer to work on an assignment alone?	Yes/No

LC	Response
Do you prefer to have lectures that cover an outline of the material for the topic and be provided with reading lists and some questions to explore for every topic?	Yes/No
Do you prefer to have no actual lectures but have everything (including lecture notes) available online?	Yes/No
Do you prefer to have all announcements made on an online learning tool (WebCT) because this facility is available anytime even if you do not attend lectures?	Yes/No

Table 6 (*continued*)

Do you prefer a learning environment that is completely online where face-to-face contact is not necessary?	Yes/No
Do you think that you have become a knowledgeable user of the internet, multimedia and the world wide web at the end of this course?	Yes/No
Did you acquired the ability to extend your multimedia and internet skills (i.e., able to explore, find and use information) unassisted?	Yes/No
Did you find designing and implementing a website a difficult task?	Yes/No
Did you find that the project in this unit was difficult or unmanageable given that the topic was open ended?	Yes/No
MT	**Response**
Do you find email a useful online tool at the beginning of the course?	Yes/No
Do you think it is useful to have an online chat at the beginning of the course?	Yes/No
Do you think it is useful to have an online forum at the beginning of the course?	Yes/No
Do you think it is practical to have online presentation instead of a normal presentation at the beginning of the course?	Yes/No
Do you think it useful to have an online calendar at the beginning of the course?	Yes/No
Do you find email a useful online tool half way through the course?	Yes/No
Do you think it is useful to have an online chat half way through the course?	Yes/No
Do you think it is useful to have an online forum halfway through the course?	Yes/No
Do you think it is practical to have online presentation instead of a normal presentation half way through the course?	Yes/No
Do you think it useful to have an online calendar halfway through the course?	Yes/No
Do you find email a useful online tool at the end of the course?	Yes/No
Do you think it is useful to have an online chat at the end of the course?	Yes/No
Do you think it is useful to have an online forum at the end of the course?	Yes/No
Do you think it is practical to have online presentation instead of a normal presentation at the end of the course?	Yes/No
Do you think it is useful to have an online calendar at the end of the course?	Yes/No
Do you think WebCT is an effective non face-to-face communication tool?	Yes/No
Do you think WebCT is a useful tool in goal setting?	Yes/No

Table 6 (*continued*)

Do you think WebCT is a useful tool in terms of interpersonal relationship management?	Yes/No
Do you think WebCT provides greater personal time management?	Yes/No
Do you think WebCT is an effective tool in project management?	Yes/No
Do you think WebCT is a useful tool in managing effective teamwork?	Yes/No
Do you think WebCT overcomes geographical and time zone problems?	Yes/No
Do you think WebCT is a valuable tool that takes into account of culture issues?	Yes/No
Do you think your overall experience with WebCT is very valuable?	Yes/No
Do you think WebCT is well fitted into the overall curriculum of this unit?	Yes/No

used random sampling, but in practice it is very difficult to be carried out, as it requires a huge sample size. An area of future research that should prove especially interesting in researching students' CS and hypermedia is to carry out a longitudinal data collection since students' CS may change with time throughout their 3 years studies.

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Appendix A

See Table 6.

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