# The effects of a Web-based Guided Inquiry Approach on Students' Achievement

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***Abstract* - Although Web technology is widely used in today's classrooms, educationists are still unsure of its capability to generate meaningful learning. As the numbers of web-based learning (WBL) materials keep increasing tremendously, more students will rely on such resources in their learning process. WBL is always seen as a platform to deliver information, and as such, most of its learning materials are linear and tutorial-based. A WBL that applies a guided inquiry approach offers an alternative as it allows the users to explore the environment based on a given problem. This study investigated the effectiveness of two learning approaches in a WBL environment (guided inquiry, GIA and tutorial, TuA) on the achievement of students with different cognitive styles (Field Independent, FI and Field Dependent, FD). Two versions of a WBL material (TuA and GIA versions) were developed for this purpose. The findings revealed that: (1) the GIA group performed significantly better than the TuA group, (2) the FI students performed significantly better than the FD students did, (3) the FI students in the GIA group performed significantly better than did the FI students in the TuA group, (4) a significant difference in achievement was reported between the FI and the FD students in the GIA group, and (5) among the FD students, no significant difference in achievement between those who received GIA and those who received TuA approaches. These findings suggest that Guided Inquiry has the potential to be an effective learning approach in a web environment.**

***Index Terms* - Guided Inquiry, Web-based Learning, Constructivism**

## I. INTRODUCTION

The use of technology in today's classroom is no longer an issue. Of late, the advent of Internet technology has brought along a huge impact in education. The World Wide Web, or better known as the Web, offers a wide range of activities for teaching and learning purposes. Educators can use it to access, disseminate and deliver information, and students can access it to seek information, generate knowledge and share ideas, as well as communicate with others. One of its greatest advantages is that it allows users to access information at anytime, and from anywhere. The Web also offers a vast amount of information ready to be accessed by anyone.

In Malaysia, although there are currently huge numbers of web sites designed for instructional purposes, many of these sites are applying a tutorial-based approach [1, 2]. In a tutorial-based web environment, the content is usually presented in a linear and sequential nature, and is followed by some forms of exercises/practices and feedback. Cognitively, those web sites lack interactivity for the users to solve problems or generate ideas. With this approach, there is not much difference if one is to learn from a textbook; reading the content which is presented linearly, and responding to the prractice items accordingly. As the Web technology offers the nonlinear and interactive features of multimedia, instructional designers should take full advantage of these capabilities when developing a web-based learning (WBL) environment. Rather than merely presenting the learners with the content, the WBL environment should prepare the learners to seek information and discover learning through exploration and interaction with the content. This inquiry approach is seen as an alternative to the traditional way of acquiring knowledge.

Inquiry has been defined in many different contexts, and it generally refers to the art and science of asking questions that are accessible, can be answered in part or in whole, and ones that lead to meaningful tests and explorations [3]. It usually involves careful observation and measurement, hypotheses creation and interpretation, as well as theory generation. It also requires experimentation, reflection, and recognition of the strengths and weaknesses of its own methods. Meanwhile, inquiry-based learning is defined as a way of acquiring knowledge through the process of inquiry. In this approach, the learners generate their own question or are posed with a question by the teacher, or by the computer as in a WBL environment. The inquiry-based learning approach usually requires a more active

role of the learners in answering the given questions or problems through discovery, investigation or experimentation. Guided Inquiry is one type of inquiry learning in which the learners will investigate a teacher-presented (or computer-presented) question using their own designed or selected procedures [4]. In education, while much thought and research have been spent on the role of inquiry in science education, this approach can be applied to many disciplines, including social sciences, humanities, or even arts. This study attempts to investigate the effectiveness of a WBL that applies a guided inquiry approach on students' performance in Visual Arts Education.

## II. THEORETICAL BACKGROUND

For the last few decades, the field of education has experienced a shift in its paradigm. Behaviorism is the first to have influenced this field, and is followed by cognitivism. Currently, constructivism is seen as an alternative for human learning. Constructivist proponents argue that individuals actively construct knowledge by working to solve realistic problems, usually in collaboration with others [5]. This theory encourages students to use active techniques such as experiments and problem solving to build more knowledge. Besides being constructive, learning should also be reflective, collaborative, inquiry-based, and evolving [6]. Through these processes, they will integrate their new knowledge with the previous one, which in turn will assist them in building their current conceptions.

Lawson (1995) has introduced Learning Cycle Model [7] which can be classified as a guided inquiry model based on constructivist principles. This model consists of three core elements, namely *exploration*, *term introduction*, and *concept application.* In a constructivist environment, the learners will begin their learning process by *exploring* a given issue, question, or problem that is related to the content. At this stage, the teacher (or the computer) will provide guidance to the learners to observe, measure, and record data or information. They are encouraged to collaborate with their peers to conduct this analysis. Then, at the next stage; *term introduction*, they will be introduced to the terms and concepts related to the topic. Here, the teacher (or the computer) will explain the concepts and terms. It is at this stage that the concepts should be clarified, and any misconceptions be corrected. In the third stage; the *concept application*, the learners will apply the concepts that they have learned to a new, different situation. This cycle will continue until the learner understands the concepts and experiences meaningful learning.

### *A. Application of Guided Inquiry Learning Approach*

In designing a WBL that utilizes a Guided Inquiry Learning approach (GIA), the authors have adapted Lawson's Learning Cycle Model. The steps or procedures suggested in the GIA approach [8] are shown in Fig. 1.

In this model designed for a WBL environment, the learning process begins with an introductory section. At this stage, the learning goals and objectives will be presented. Also, this section provides the overall structure of the WBL, which can be in the form of a concept map, an outline, or a hierarchy, as well as the instructions on how to use the WBL.

Then, several questions are posed to the learners. This very pertinent element of the GIA Approach serves to stimulate the learners' discovery process or to allow them to reflect on the questions. For example, in teaching *Color Theory* in Visual Arts Education, the computer may ask '*Why do fast food restaurants are usually painted in red and yellow?*' (Fig. 2). If the learners are ready, they may respond to the questions, or they may want to explore the relevant information first. Fig. 3 and Fig. 4 depict two examples of guidance for the students to explore the relevant topic to solve the problem given earlier. Also, if they fail to provide a correct response (Fig. 5), they will be guided by the WBL. If the learners answer correctly (Fig. 6), a concept or a rule will be presented. The correct response indicates that a new knowledge has been generated by the learners, and the presentation of the new concept or rule (Fig. 7) helps to strengthen the learners' understanding of the new knowledge. This new concept or rule will then be used for the subsequent problems or questions (Fig. 8). These whole activities indicate an inductive, exploratory process of the GIA approach.

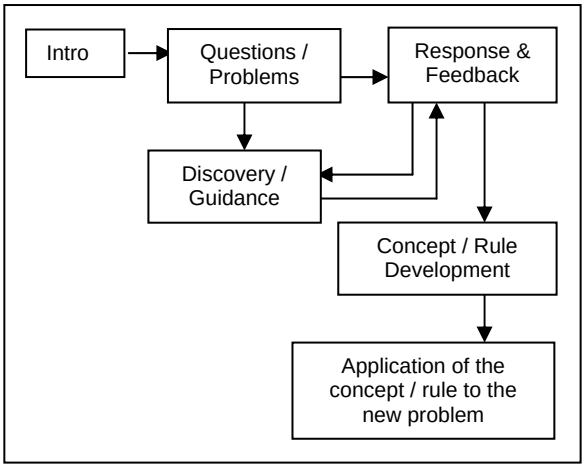


Figure 1. A Guided Inquiry Approach [8]

The GIA is different than the traditional, tutorial approach proposed by Alessi and Trollip [6]. A tutorial approach (TuA) begins with an introductory section which informs the learner of the purpose and nature of the lesson. It is then followed by a cycle which begins with the presentation and elaboration of the information. A question is asked and the learner has to respond to this question. The program (or WBL) will judge the response and the learner is given a feedback to improve his comprehension. At the end of each cycle, the program will make a sequencing decision to determine what information should be treated during

the next cycle. This cycle will continue until the lesson is terminated either by the learner or by the program.


Figure 2: A situation / problem that requires students' response

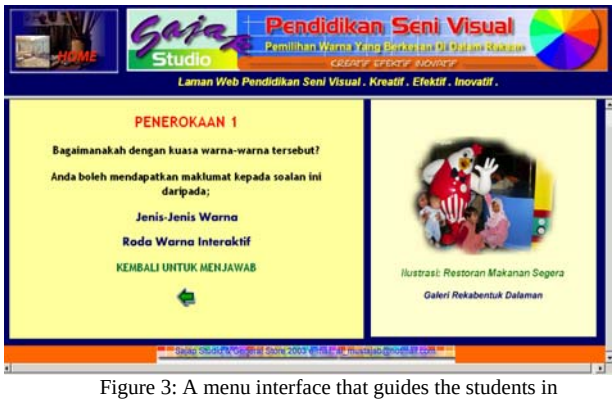


Figure 3: A menu interface that guides the students in exploring the content


Figure 4: More internal links to the content


Figure 5: Feedback for Incorrect Response

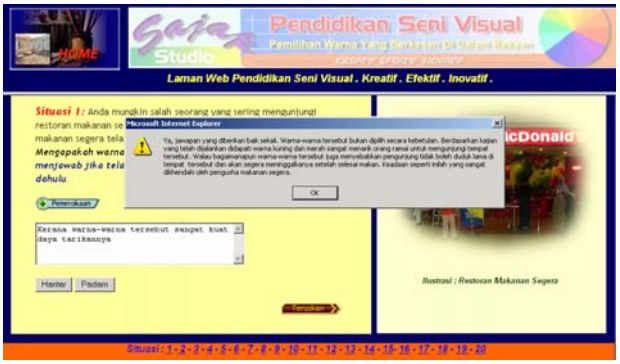


Figure 6: Feedback for Correct Response


Figure 7: Concept / Rule Development


Figure 8: Concept / Rule Application

## B. *Field Dependence-Independence Cognitive Style*

Field Dependence-Independence (FD-I) cognitive style describes the degree to which a learner's perception or comprehension of information is affected by the surrounding perceptual / contextual field [10]. *Field independent* (FI) people tend to experience parts as distinct from the whole organization. They do not rely on others in processing an input or knowledge received, and they are also able to restructure the knowledge. Moreover, they prefer to work individually rather than in group. On the other hand, the *field dependent* (FD) people tend to experience parts as integrated within the whole, prefer to socially interact with others and rely on others during the learning process.

Studies have shown that FI and FD students learned differently when accomplishing the same task in a computer-based environment. FD individuals find it difficult to locate the information they are seeking because other information from the surrounding tends to mask the information searched [11]. On the contrary, FI people do not have the problem in recognizing and selecting the important information from the surrounding field. They are more likely to recognize, restructure, or represent information to suit their own needs, conceptions, or perceptions.

## III. Research Methodology

This study attempts to investigate the effects of learning approaches and field dependence-independence cognitive style on students' achievement in a WBL environment. Two versions of a WBL environment on Color Theory were developed. How do students perform in a WBL environment with different learning approaches? What is the preferred WBL approach for students of different cognitive styles?

### *A. Research Design*

A 2x2 (WBL approach x cognitive style) factorial design was employed in this quasi-experimental study. Two independent variables were investigated, the first being the approaches in the WBL (GIA and TuA), and the second was cognitive style (Field Independent; FI, and Field Dependent, FD). The control group received the TuA approach while the experimental group received the GIA treatment. Meanwhile, the students' achievement based on their pretest and posttest scores was identified as the dependent variable.

A total of 141 high school students (Form Four or equivalent to Grade 10) enrolling in the Visual Arts Education from two different schools were involved in this study. They were randomly assigned to each of the two treatment groups.

### *B. Research Instruments*

Two versions of a WBL environment were developed in this study. The first was the WBL with GIA approach, and the second was the WBL with TuA approach. The topic chosen for both versions was 'Color Theory' which is part of the Visual Arts Education syllabus for Malaysian high school students..

The Group Embedded Figures Test (GEFT) was used to determine the subjects' level of FD-I. It is a group-administered, 25-item test that requires 20 minutes to complete. It measures the ability to locate a simple figure within a larger complex figure. A subject will be assigned as FD if his or her score fell below the group GEFT mean score or as FI if the score fell above the GEFT mean score. The GEFT reliability is reported to be 0.82 and its validity is between 0.63 and 0.82 [12]. Researchers have demonstrated that the GEFT can be used as a cognitive measure with non-native English speakers of various cultural backgrounds [13]. In this study, the GEFT mean score of the sample was 10.7. Therefore, students who scored 10.7 and above were categorized as FI, and those who scored below 10.7 were categorized as FD.

The pretest and posttest were administered to assess the students' performance on 'Color Theory'. The pretest was administered prior to the treatment, while the posttest was administered immediately afterward. These paper-and-pencil tests consisted of 25 multiple choice items and the students were allocated 35 minutes to answer each test.

### *C. Procedure*

The subjects were first briefed about the study. Then, the GEFT was administered to them. Then, they went through an orientation session to familiarize themselves with the WBL environment and to ensure that they had the same general degree of comfort during the instructional treatment. Next, the pretest was carried out to them.

Next, the GEFT scores were used to assign the subjects to the control and experimental groups. Then, the samples went through the instructional treatments for two hours. Each student was given a computer workstation to learn the WBL material individually. The students were then given the posttest immediately after the treatment session.

## IV. Findings And Discussion

In order to identify whether there is any significant difference in the pretest scores between the control and experimental groups, an analysis was first being carried out. A *t-test* analysis revealed that both groups differed significantly prior to the treatment (t : 2.25; p: 0.03), with the GIA group performed significantly better than the TuA group (GIA mean : 47.9, TuA mean: 44.08). Thus, due to this significant difference prior to the treatment, Analysis of Covariate (ANCOVA) was used for data analysis in which the pretest score was identified as the covariate. Also, due to the application of ANCOVA, the posttest mean scores reported in the following sections were based on the adjusted means instead of the observed means.

### *A. Results*

The descriptive statistics of the adjusted posttest scores for the two treatment groups and the two cognitive style groups involved in the study are shown in Table I. Table II indicates the ANCOVA analysis for the WBL approaches and cognitive style as the two main effects of this study, while Table III indicates the Pairwise Comparisons between the four groups (GIA – FI, GIA-FD, TuA-FI, and TuA-FD).

TABLE I.
DESCRIPTIVE STATISTICS MATRIX OF THE ADJUSTED POSTTEST MEAN SCORES

| | | WBL approach | | |
|---|---|---|---|---|
| | | GIA | TuA | Total |
| FD | n | 29 | 41 | 70 |
| | M | 51.32 | 54.32 | 54.49 |
| | SD | 1.30 | 1.15 | 1.01 |
| FI | n | 39 | 32 | 71 |
| | M | 63.54 | 54.71 | 58.02 |
| | SD | 1.18 | 1.37 | 1.01 |
| Total | n | 68 | 73 | 141 |
| | M | 59.81 | 52.97 | |
| | SD | 0.98 | 0.94 | |

TABLE II.
ANCOVA FOR COGNITIVE STYLES AND WBL APPROACHES (ADJUSTED POSTTEST)

| Source | SS | df | MS | F-value | p-value |
|---|---|---|---|---|---|
| Cognitive Style | 437.81 | 1 | 437.81 | 6.11 | 0.02* |
| WBL approaches | 1587.12 | 1 | 1587.12 | 25.04 | 0.00* |

* $p < 0.05$

TABLE III
PAIRWISE COMPARISONS (ADJUSTED POSTTEST)

| | | Mean Diff. | Signif. |
|---|---|---|---|
| | TuA-FI | 8.827 | 0.00 |
| GIA – FI | GIA – FD | 12.217 | 0.00 |
| GIA – FD | TuA-FD | - 3.00 | 0.513 |

Research Question 1: Is there any significant difference in terms of achievement between the GIA and TuA groups?

Based on the ANCOVA result (Table II), there is a significant difference in terms of achievement between the GIA and TuA groups ($F_{1,138}$ : 25.04, $p < 0.05$). This result clearly indicates that the GIA group performed significantly better than the TuA group ($M_{GIA}$ : 59.81; $M_{TuA}$ : 52.97).

Research Question 2: Is there any significant difference in achievement in a WBL environment between FI and FD students?

The result in Table II indicates a significant main effect for the two levels of field dependence-independence, ($F_{1, 138} = 6.11$, p : 0.02). The FD and FI students exhibited significant differences in achievement, with the latter group of students performed better than the former group in the achievement test ($M_{FI}$: 58.02; $M_{FD}$ : 54.49).

Research Question 3: Is there any significant difference in achievement between FI students who received GIA and FI students who received TuA approach?

A pair-wise comparison analysis (Table III) between the FI students in the GIA group and the FI students in the TuA group revealed $p<0.05$ with the mean difference of 8.83 ($M_{FI\text{-}GIA}$ : 63.54; $M_{FI\text{-}TuA}$ : 54.71). This indicated that the FI students in the GIA group performed significantly higher than the FI students did in the TuA group.

Research Question 4: Is there any significant difference in achievement between FD and FI students who received the GIA approach?

A pair-wise comparison analysis (Table III) between the FI and FD students in the GIA group revealed a p-value of <0.05 with the mean difference of 12.22 ($M_{FD\text{-}GIA}$: 51.32; $M_{FI\text{-}GIA}$: 63.54). This indicated that the FI students performed significantly higher than the FD students did in the GIA group.

Research Question 5: Is there any significant difference in achievement between FD students who received GIA approach and FD students who received TuA approach?

A pair-wise comparison analysis (Table III) between the FD students in the GIA group and the FD students in the TuA group indicated an insignificant difference in achievement (p:0.513) with the mean difference of 3.00 ($M_{FD\text{-}GIA}$: 51.32; $M_{FD\text{-}TuA}$: 54.32). However, although not significant, the FD students who received the TuA group had performed slightly better compared to those in the GIA group.

### *B. Discussion*

The purpose of this study was to investigate the effectiveness of a Web-based Guided Inquiry Approach on students' learning. The topic chosen for this study was 'Color Theory', which is part of the Visual Arts Education Syllabus for Malaysian high school students.

The first finding of this study indicated that students who received the Guided Inquiry approach performed significantly higher than those who received the Tutorial Approach. In the Guided Inquiry approach, the students were first given a situation or problem. In order to solve the problem and generate meaningful learning, they had to explore, discover, generate hypothesis and develop related concepts. In this study, these activities are supported with the existence of various internal- and external- web pages or hyperlinks related to the topic. The students were then able to apply the new concepts learned to a new situation or problem. This finding also supported the idea of a teacher (or computer) as the facilitator, as suggested in Lawson's Learning Cycle [7] and Collins and Stevens' Guided Inquiry [14]. In contrast, the students in the tutorial approach were passive receivers of information. The students in this group received the content presented in a linear and sequential manner. This deductive, tutorial approach environment did not provide any opportunity for the students to conduct active exploratory and discovery activities which are required for meaningful learning to take place.

A significant main effect of cognitive styles on the students' achievement was also observed in this study. In particular, the FI students performed significantly better than the FD students did. This finding supported the notion that FI individuals are more likely to demonstrate superior recall because of their greater

restructuring skills [10], especially in the complex environment of the Web. In addition, in both the GIA and TuA groups, each student had to learn the material on his or her own. Unlike the FD students who prefer to work in a team, the FI students prefer to work and learn individually [10]. Therefore, the FI students performed better as the WBL environment in this study was designed for individual learning activity.

This study also found that the FI students in the GIA group performed significantly better than the FI students did in the TuA group. Again, the non-linear, exploratory nature of the GIA approach was an advantage for the FI students as it suits their cognitive styles. However, the FI students in the tutorial approach were at disadvantage due to the fact that this environment did not promote discovery learning as they preferred.

In addition, the fourth finding revealed that among the students who received the GIA approach, the FI students also significantly outperformed the FD students. As the GIA approach offers a non-linear, unstructured environment, it proved to be of help for the FI students as they would usually prefer such freedom during their learning process. On the other hand, FD students in the GIA group were not able to perform, as they usually learn better with a linear, structured material.

The fifth finding indicated an insignificant difference in achievement between the FD students who received the GIA approach and the FD students who received the TuA approach. Even though there was no significant difference, the analysis result has favor toward the tutorial group. This indicates a slight preference among the FD students in this study to achieve better in a traditional, tutorial mode as compared to the FD students in the GIA group. Again, this indicates the preference of the FD students to learn in a linear, structured manner as in the TuA version.

## V. SUMMARY

Overall, the application of Guided Inquiry learning approach that focuses on problem solving through exploration, concept development and application, has the potential to improve students' learning in a WBL environment. Therefore, more web based learning materials that apply the guided inquiry approach should be developed. Also, individual differences in terms of cognitive style should also be of concern in designing such materials as these may affect the students' learning process. In addition, unlike previous studies on inquiry based learning that focused on science-related courses or disciplines, this study has highlighted the importance of applying this approach in a WBL environment for Visual Arts Education. This study has proved that inquiry learning is applicable to any discipline, and as such, more studies need to be carried out to other non-science disciplines.

## REFERENCES


[1] Umar, I. (2003) *An Evaluation of Malaysian Educational Web Sites.* Proceedings of the 16th Malaysian Educational Technology Convention.

[2] Atan, H., Abdul, A.H., Saw, K. G., & Idrus, R.M. (2003). *Science Educational Software in Malaysian Smart Schools: An Evaluation of Pedagogical and Communicative Dimension*. Proceedings of the 16th Malaysian Educational Technology Convention.

[3] Hebrank, M. (2000). *Why Inquiry-Based Teaching and Learning in the Middle School Science Classroom?* Retrieved Jan 5, 2006, from www.biology.duke.edu/cibl/inquiry/why_inquiry_in_ms.htm

[4] Herron, M.D. (1971). The nature of scientific inquiry. *School Review*, 79(2). 171-212.

[5] Duffy, T.M., Lowyck, J. & Jonassen, D.H. (1993). Introduction. In T.M. Duffy, J. Lowyck, & D.H. Jonassen, (Eds), *Designing Environments for Constructive Learning* (pp. 1 – 5) Berlin: Springer-Verlag.

[6] Thirteen Ed Online (2004). *Constructivism as a Paradigm for Teaching and Learning*. Retrieved January 7, 2006, from http://www.thirteen.org/edonline/concept2class/constructivism/index.html.

[7] Lawson, A. E. (1995) *Science Teaching and Development of Thinking*. Belmonth, CA: Wadworth Publ.

[8] Maswan, S. & Umar, I. (2004). *Inquiry Approach and Problem based Learning in a Web Environment*. Proceedings of the National e-Learning Conference, 2004.

[9] Alessi, S.M. & Trollip, S. R. (2001). *Multimedia for Learning: Methods and Development* (3rd Ed.) Boston: Allyn and Bacon.

[10] Witkin, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977). Field dependent and field independent cognitive styles and their educational implications. *Review of Educational Research, 47*(1), 1-64.

[11] Jonassen, D. H. & Grabowski, B. L (1993). *Handbook of Individual Differences, Learning and Instruction.* Hillsdale, NJ: Lawrence Erlbaum.

[12] Chinien, C. A. & Boutin, F. (1992). Cognitive style FD/I: An important learner characteristic for educational technologists. *Journal of Educational Technology Systems, 21*(4), 303-311.

[13] Leader, L. F. & Klein, J. D. (1996). The effects of search tool type and cognitive style on performance during hypermedia database searches. *Educational Technology Research and Development, 44*(2), 5-15.

[14] Collins, A., & Stevens, A. L. (1983). A cognitive theory of inquiry teaching. In C.M. Reigeluth (Ed.) *Instructional Design Theories and Models: An Overview of Their Current Status* (pp. 247- 278). Hillsdale, NJ: Lawrence Erlbaum Assoc. Publishers.


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