USING METACOGNITIVE STRATEGIES IN A VIRTUAL REALITY ENVIRONMENT FOR FIELD DEPENDENT LEARNERS

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Abstract

The purpose of the study reported in this paper was to develop and evaluate a method for teaching field dependent (FD) learners using a Virtual Reality Learning Environment with Metacognitive Strategies (VRLEMS). The effect on student learning was measured using pre-test/post-test and compared to a group of FD learners taught in a traditional lecture environment. The result revealed that FD learners' learning increased by a statistically significant amount after participation in the VRLEMS and they had a statistically significant higher achievement than those learning in a traditional classroom.

Introduction

The majority of vocational learners in Asia come from national middle schools [1], and have field-dependent (FD) cognitive styles [2] and earn lower grades than learners who have a field-independent (FI) cognitive style [3,4].This agrees with a study in Thailand [5]. FD learners have more learning problems in school than do FI learners [6,7]. Also FD learners tend to ask for help more often than field independent learners [8].

A more effective teaching method is therefore needed to provide FD learners with a useful learning strategy so they can better analyze and solve problems and improve their learning abilities and learning achievment. Such an approach may require use on metacognitive strategies [9].

An analysis of field dependence-independence cognitive style functioning concluded that FD learners could be trained in metacognitive strategies to improve learning in different contexts [10]. FI and FD learners do not differ in learning ability but may respond differently to the way the content is presented as well as to the specific learning environment [11,12].

This implies that a method could potentially be developed to teach FD learners more effectively by compensating for the differences in their learning style and also helping them to use metacognitive strategies.

Metacognitive strategies can be successfully modelled using computers. Use of computers has the advantage of making tacit thinking processes overt, so they can be externalized and accessible as objects of close reflection and evaluation [13]. The computer as tutor [14] can help learners develop self-correction skills for problem solving [15]. Metacognitive strategies affect learners differently depending on their cognitive style [16]. FI learners use cognitive and metacognitive strategies [17] but there is no research to show that FD learners use these strategies.

Prior research has shown that Thai vocational learners adopt VR training [18]; moreover FD learners were more motivated and had more positive attitudes than FI learners while working in a VR learning environment [19].

The Purpose of this Study

The purpose of the study reported in this paper was to test the hypothesis that using a Virtual Reality Learning Environment with Metacognitive Strategies (VRLEMS) will improve the learning of FD learners.

The study compared learning between the learners exposed to the VRLEMS and learners exposed to a traditionally taught environment to determine if there was a significant relationship between learning and the VRLEMS used for FD learners.

Literature Review

Virtual Reality

VR is an environment in which a person experiences a three-dimensional computer-generated virtual representation of reality and is able to move around in the environment and see it from different angles [20]. The VR is used in many fields including education [21]. VR environment can affect users physically [22] and emotionally [23]. The effects on the brain of VR can be measured using brain monitoring [24].

Field-dependent/Field-independent Learner

Cognitive styles refer to preferred ways individuals choose to perceive, organize, analyze or collect information or experiences. Such styles can be described by the construct: Field-Dependence/Field-Independence [25]. A more FD style tends to rely on or accept as concrete the external environment while a more FI style will tend to be more analytical with willingness to work on the environment.

FD learners may benefit from more interaction with fellow learners and the teacher and be more successful with a more structured content that requires less analysis to understand. FD learners may prefer more direct instruction or definition of the material in situations that involve restructuring abilities [26]. FI learners are better at analytical activities. They can solve complex problems, recall information, isolate facts and distinguish the relevant from the irrelevant; they can recognize an item as discrete from its background. Also they perform better on standardized tests [27].

Metacognitive strategies

Metacognitive strategies are strategies that monitor or regulate cognitive strategies, including checking the outcome, planning, monitoring, testing, revising, and evaluating [28]. They include directed attention and self-evaluation, organization, seeking practice opportunities, setting goals and objectives [29].

A number of models of metacognitive strategies (which are derived from different conceptualizations of metacognition) have been proposed. Some are more general and provide a theoretical framework (such as Flavell's and Brown's models). Others concentrate on specific aspects of metacognition (such as memory processes and metamemory) [30]. Metacognitive strategies for a Virtual Reality Environment (VRE) by Kaewprapan and Suksakulchai [31] was the basis for the model used in this study. This model is called the Virtual Reality Learning Environment using Metacognitive Strategies (VRLEMS). The model shows the inter-relationship between elements and how they combine to function together. The use of each element is as follows.

1. Introduction/background: To provide resources, tools, and educational materials for content, knowledge, and how to use the environment.
2. Planning: To guide, analyze, identify goals, define learning problems and rules as well as the overall structure of the topic and the instructional approach.
3. Action: To guide and motivate the learner to interact with the VRE and participate in the virtual reality scenario or game.
4. Coach & help: To provide assistance and individual help while observing the learners and providing explanation and reasoning to help them understand.
5. Regulation: To lead learners to do an overview of a problem on their own and then put them in roles in individual, collaborative or competitive learning situations where they

find resources so they can solve the problems using their own skill and effort.

6. Evaluation and feedback: To direct learners in self-regulated learning using self questioning, performing personal self-assessments, maintaining a check list, expressing their thoughts in a journal and performing internal and external reflection.
7. Transferring to real life: To provide learning experiences which are intimately related to the use of the skill. To reproduce reality using simulation techniques which make the roles and social context effective for learning.
8. Interaction: To provide learner interaction with the VR environment and the roles and perception in the VR.

Materials and Method

The Instruments

The Group Embedded Figures Test (GEFT).

The GEFT was developed by Oltman, Raskin, and Witkin in 1971 [32]. It is a frequently utilized instrument to measure an individual's degree of field dependency by tracing simple forms in the larger complex figures.

Pre-test and post-test were used. These were multiple choice format tests with 30 questions having 4 choices per question. The tests were validated by a panel of experts.

Virtual reality learning environment and content. The VR was created based on the Metacognitive Strategies model (VRLEMS). The environment was validated by three instructional multimedia design specialists. The content validity was established through qualitative expert reviews by a panel of three experts.

Participant

The total sample was 173 metal technology vocational students from public universities and vocational colleges in Thailand. They were tested using GEFT to determine their cognitive styles. There were 120 FD learners selected for this study from the total sample based on this testing and they were sorted by their previous semester grade point average (GPA). They were split into 2 classes using a paired sampling method which meant each class had 60 learners: an experimental class and a control class. Each class had mixed high and low GPAs and learners were compared by mean of GPAs in almost the same numbers. The details are shown in Table 1.

GPAs	VR class		Traditional class		Total
	n	%	n	%	
low	35	58.33	33	55	68
high	25	41.67	27	45	52
total	60	100	60	100	120

Table 1: Subject Population and sample groups GPA characteristics.

Procedure

1. The learners were given the pre-test on safety welding issues.
2. Participants in the experiment group were provided with the opportunity to use a VRLEMS which was created by one of the authors of this paper. Learners would see a simulated environment from a first person viewpoint.
3. The control group was taught in a traditional environment which used the same content and lesson plan as the VRLEMS did. Both groups completed the post-test.

Data Analysis

The statistical analyses employed were percentage, mean, standard deviation, t-test dependent, and t-test independent

Systems Approach

The VRLEMS was called "Safety Lab Safety Life". The architecture is shown in Figure 1. The environment was presented from a 1st person perspective with safety welding instructional content and scenarios based on real situations that would make it easy to transfer acquired knowledge to real life.

1. Teacher provides content based on curriculum and strategy
2. Admin installs the content on a JAVA sever
3. Virtual reality environment is generated and is accessible via internet
4. Electronic Devices built using a Java platform are connected to the internet by users

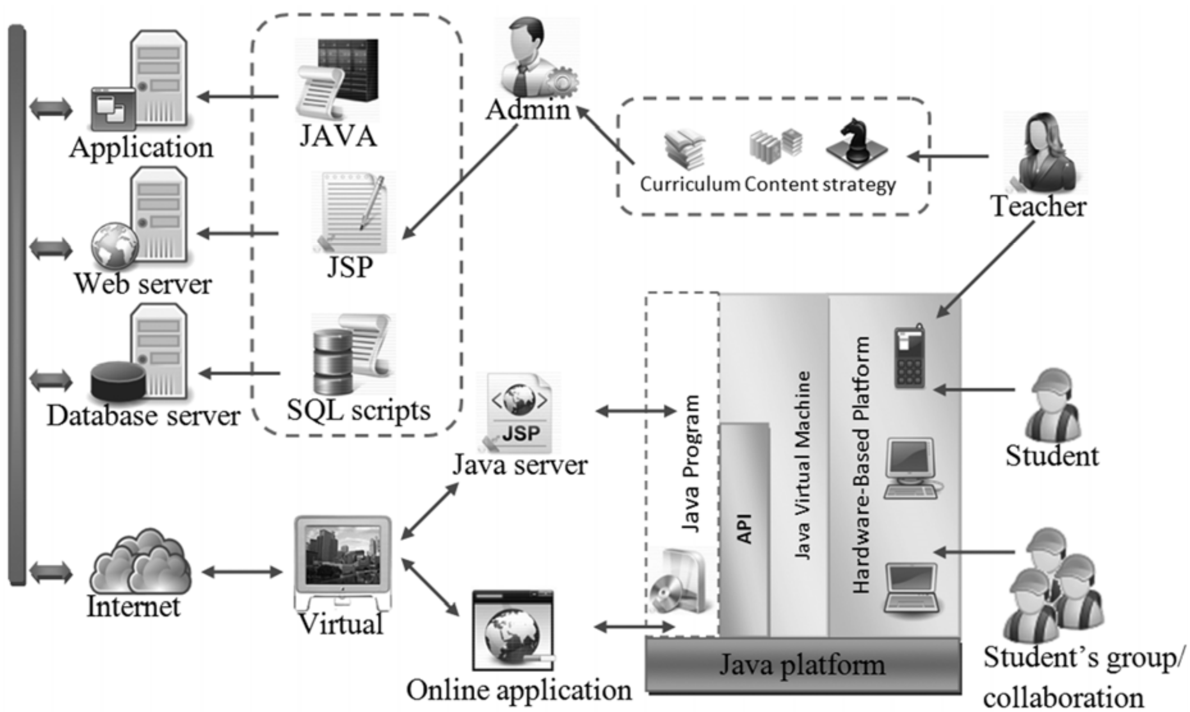

Figure 1: The architecture.

Safety Lab Safety Life System Overview

The learners connect to a website, create a user account, download a program and then access the lessons and the VRLEMS environment.

There are two levels of instruction. The first simulates safety preparations and second level simulates real life with tasks to perform and problems for the learner to solve. Users' situational (progress and state) data were saved so that when users wanted to leave the environment they could return to the same point in which they left the environment. User activities and conversation in the environment were saved for later content analysis. The lesson flow is shown in Figure 2.

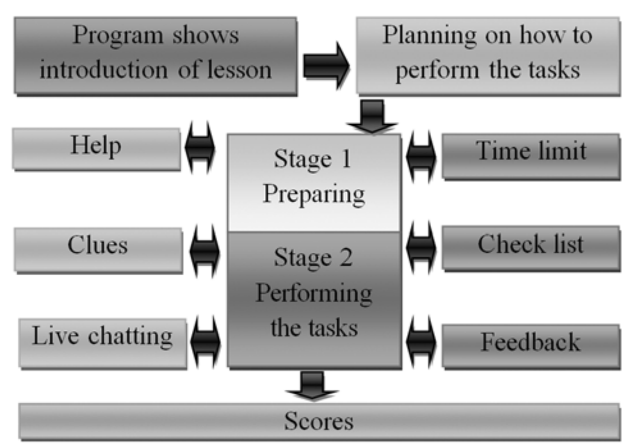

Figure 2: The lesson flow.

The implementation of the strategies

The implementation of the VRLEMS model shown below details metacognitive elements and how they function in the system. The users' screen examples are shown in Figure 3-4.

Figure 3: Users' screen examples**.**

1. Introduction/background: Learners are shown a lesson overview on the main page.
2. Planning: Learners are presented with tasks to perform and create plans (checklists) on how to perform the tasks, deciding how to accomplish tasks by listing steps in a "pop-up" plan which can be referred to later as a checklist. The environment components allowed users to set their goals; then, the learners get a mission such as to find the proper welding suit, find the components, and outfit themselves.
3. Action: Learners interactions with the game story are guided and motivated by the visual environment. The environment puts users in roles that would require them to perform procedures that would ensure their own personal safety as well as make the simulated welding lab a safe working environment.

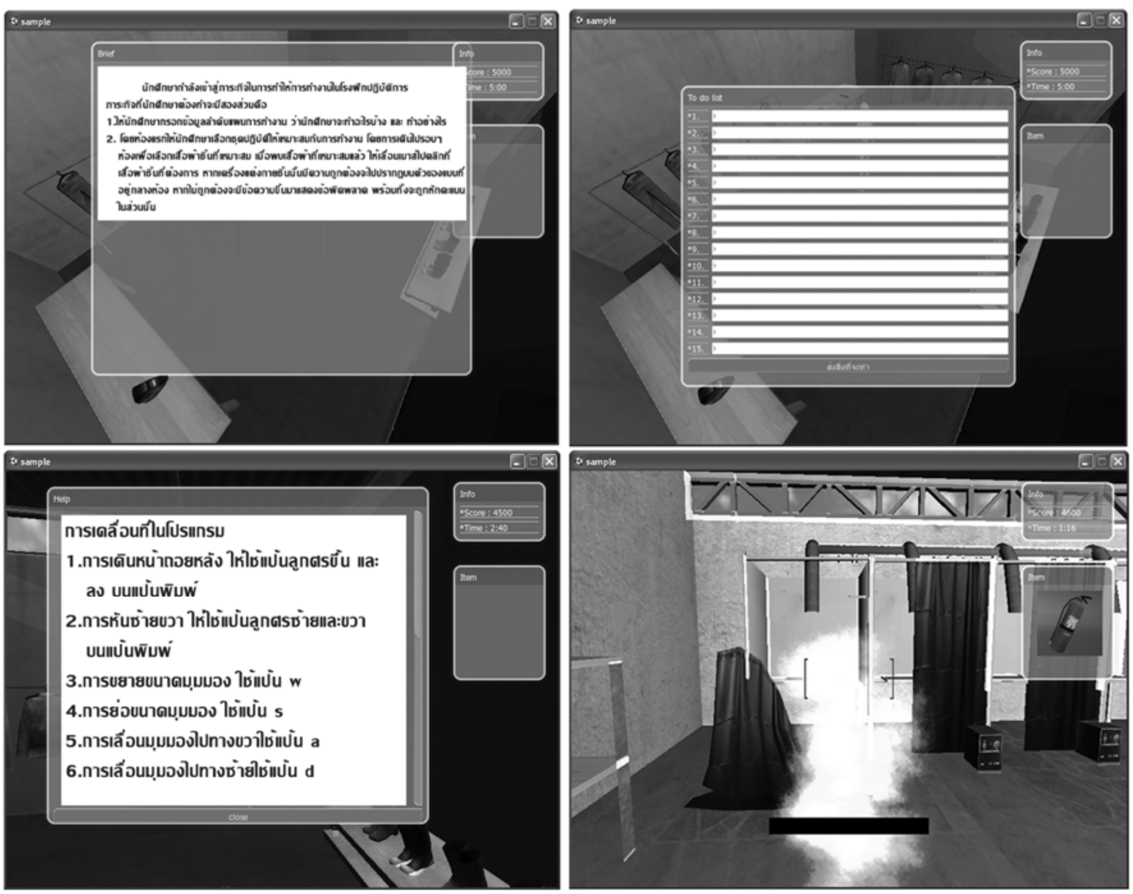

Figure 4: User's screens clockwise: Introduction, Planning, Coach & help and Action.

4. Coach & help: Direct assistance and individual help are provided from online communication with the teacher, online help and narrative support, and task description on the game main pages.
5. Regulation: the learners take on the role of a welding lab participant and are given guidance and cues to acquire resources (e.g., safety equipment) and perform realistic welding lab tasks to achieve assigned goals on a schedule using their own knowledge and skill. The lesson scenarios are timed. The learning success criteria are: completing the lesson goals in the allotted time with minimal assistance; errors must be below a certain threshold. The missions involve finding the components and performing tasks in the correct sequence in a limited time. The more assistance the learner requires from the system or the teacher, the lower their score.
6. Evaluation and feedback: Scores and point increments (or decrements along with pop-up error messages if they do a task incorrectly) allow learners to measure their performance and perform self-evaluation. Learners can review their plan and checklist, gauge their progress and review their learning activities. If learners selected the wrong pieces (or in the wrong order) or ask for clues or direction in the environment they will lose some of their score. Learners are successful when the mission is completed in time with few mistakes.
7. Transferring to real life. The environment accurately depicts: real life scenarios, risks, safety resources and welding lab tasks and procedures; uses effective role simulation techniques to reproduce real life situations for learners interaction; and a social context to enhance the learning experience. The lessons focus on real situations and problems that might happen in a welding lab (such as installing fire extinguishers, cleaning, prevention of electrical problems such as a short circuit and health care). The learners can then be evaluated by the teacher to verify that they can apply the learned skills outside of the VR environment.
8. Interaction: Learners interact with the learning environment and have navigational capability by giving inputs via mouse and keyboard and experiencing responses from the system on the VR monitor display and from an audio system.

Results

The study compares the learning achievement of FD vocational learners taught in a VRLEMS and a similar group of learners taught in a traditional environment. The results are as follows:

Both control group and experimental group are approximately equal for Pre-test scores (Classroom = 11.57 and VR = 11.45).The experimental group has significantly higher Post-test scores(Classroom=12.72 and VR=15.93).

	Mean	N	SD	Std. Error Mean
Post -test score	15.93	60	4.532	.585
Pre -test score	11.45	60	4.575	.591

Table 2: Paired sample statistics: Learners in the VRLEMS' Pre-test/Post-test.

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	SD	Std. Error Mean	Lower	Upper			
Pre-test - Post-test	4.483	.892	.115	4.253	4.714	38.916	59	.000

Table 3: Paired Samples: Test Pre-test/post-test scores of learners in the VRLEMS.

As shown in Table 2 and Table 3, the absolute value of the t value of 38.916 is greater than the critical value of 2.010, and the p-value of 0.000

is less than alpha of 0.05. Therefore the null hypothesis is rejected. The post test mean score (Mean = 15.93, SD = 4.532) is significantly greater than the pre test mean score (Mean = 11.45, SD = 4.575).

As shown in Table 4 and Table 5, The t value of 3.756 exceeds the critical value of ± 1.9808 and the p-value of 0.000 is less than alpha of 0.05. Therefore the null hypothesis is rejected. There is a significant difference in the mean learning achievement between those FD learners who enrolled in the VRLEMS and those learning in traditional classroom. Specifically, those in the VRLEMS had a better learning achievement (Mean = 15.93, SD = 4.532) than those in the traditional classroom(Mean = 12.72, SD = 4.844).

The study showed that most of the learners who studied in the VRLEMS achieved a higher post-test score than their own pre-test score indicating that their learning achievement was improved and the VRLEMS was a more effective teaching method. When comparing the learners who studied in a traditional classroom with the VRLEMS taught learners, the mean score showed that overall, a high number of learners in VRLEMS earned better test scores.

Environment	N	Mean	SD	Std.Error Mean
VR	60	15.93	4.532	.585
classroom	60	12.72	4.844	.625

Table 4: Learners in the VRLEMS and traditional classroom’s Post-test score.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
				t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.						Lower	Upper
Post-test	Equal variances assumed	.684	.410	3.756	118	.000	3.217	.856	1.521	4.912
	Equal variances not assumed			3.756	117.482	.000	3.217	.856	1.521	4.913

Table 5: Independent Samples Test:Post-test scores of learners in the VRLEMS and traditional class.

Discussion and Conclusions

From the results, learning achievement increased significantly after participation in the VRLEMS. This provides evidence for the efficacy of the VRLEMS. Additionally, those FD learners who enrolled in the VRLEMS have significantly better learning achievement, indicated by their score, than those learning in a traditional classroom. This provides evidence that the VRLEMS is related to learning achievement. There are two reasons for this; first, FD learners’ cognitive style makes them learn in different ways than FI learners and the VRLEMS was adapted to the FD learners[33]. The second reason is that the use of Metacognitive Strategies is the right approach to help FD learners [16,34].

FD learners like having social interactions and relationships [35] and the VRLEMS provided them a useful and enjoyable way to interact with other learners, teachers, and the environment itself which is one of the VRLEMS ' recognized attributes.

It is not easy for FD to break information into isolated parts [36-38]. Therefore, the VRLEMS gave them coaching and assistance in several ways to continue their learning and overcome this obstacle, thus compensating for their weakness in this area. Beside this, the VRLEMS let them plan and think about what they are going to learn which help them get the whole picture of their study assignments as FD learners cannot map their own learning scope [35].The way that the VRLEMS kept giving them information and feedback helped them improve their self-awareness, which FD learners probably do not possess adequately enough [39].

Furthermore, learning in a VRLEMS made it easier to transfer their virtual situation to their real life as the environment can simulate any kind of situation that will occur in real life without danger to the learners [40]. Most learners felt free to learn and attempt new activities in the virtual environment. Moreover, Sulbaran and Baker [41] also showed that learners usually enjoy VR training more than other traditional training methods and that they retain knowledge gained from VR training longer than that gained using other methods.

This study strongly agrees with Bokyeong, Hyungsung, and Youngkyun [42] that considered Metacognitive Strategies as a success strategy for game base learning. Researchers point out that thinking the processes of listening, discovering, taking note and speaking cover 3 of the Metacognitive Strategies; i.e. self-planning , self-monitoring and self-evaluation.

The significance of this study is that it shows, based on the experimental data, that a VRLEMS is beneficial for FD learners. The authors could also infer that a VRLEMS may be a skills training method that is relatively easy to use and implement. It is also cost-effective and can be used to simulate unsafe situations without any danger to learners. Future research could consider more on these topics.

However the method used to test the learners' achievement, a one group pre test – post test only design, may be a limiting factor on the conclusiveness of the positive effects. Further research to validate these results with a larger sample group, longer exposure to the VRLEMS and improved test assessment should be considered.

In conclusion, a VRLEMS is an effective means to increase dependent cognitive style vocational learner achievement. The results of the study show that a VRLEMS improves learning achievement by a statistically significant difference compared to a traditional environment. We believe that this result implies that the VRLEMS has potential for being a practical method for improving classroom achievement and can be an effective tool to use in classroom activities.

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