PERSONALIZED LEARNING ENVIRONMENT BASED ON COGNITIVE STYLES FOR MENTAL MODEL DEVELOPMENT IN LEARNING CHEMICAL BONDING

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UNIVERSITI TEKNOLOGI MALAYSIA
PERSONALIZED LEARNING ENVIRONMENT BASED ON COGNITIVE STYLES FOR MENTAL MODEL DEVELOPMENT IN LEARNING CHEMICAL BONDING

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The purpose of this research is to develop a personalized learning materials based on students’ preferences in cognitive style, which are Field Dependent (FD) and Field Independent (FI), in learning chemical bonds. The learning materials were designed and developed based on the characteristics of the cognitive styles and further integrated in the website. The effect of the website was investigated in order to promote students’ achievements, students’ mental model developments and their pattern of interaction while learning using the website. The pattern of interaction focused on five types of interaction, which are learner-instructor, learner-self, learner-learner, learner-content and learner-interface interaction. The research samples consist of Form 4 students from a school located in Johor Bahru. A combination of qualitative and quantitative methods has been employed in data collection and analyzing the research data. The findings show that students had a positive improvement in their achievement in learning chemical bonds. Beside, students had also developed a scientific mental model after learning using the website. Besides this, students categorized under FD showed the highest total hit of interaction and enjoyed using all the applications provided on the website as compared to FI students. This showed that the FD students were more active and socially orientated while learning using the website as compared to FI students. However, both types of students showed positive improvement in their achievement and in their mental model development. In conclusion, the focus on emphasising individual differences to promote students’ learning is a vital factor to be considered, as this aspect proves valuable for both students and teachers.
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CHAPTER 1

INTRODUCTION

1.1 Introduction

Technology plays a fundamental role in making the teaching and learning process more effective. Roblyer (2003) has identified two changes when technology was integrated into the education system. The first change is the increasing number of references and tools that were used by teachers and students. The second change is the shift in learning strategies that the flexibility of computer technology affords. Traditional approaches usually involve learning being one-way or linear. Thus, the existence of computer technology in a classroom promises to change the passive learning approach to an interactive and dynamic learning process (Davies, Lavin, and Korte, 2008; Loch and Donovan, 2006). This is because the computer has great potential for enhancing teaching and learning outcomes (Fisher, 2010; Suchańska and Kęczkowska, 2007).

However, in recent years, the education field has moved rapidly towards implementing an online learning system. The implementation of web-based learning increased year by year until the launch of Web 2.0 in our education system. The characteristics of Web 2.0 have accelerated the changes in education and have also influenced the world by giving control of tasks to the learner (McLoughlin and Lee, 2010). Since learners were given authority to control their own learning, it is important to ensure that they engage and take that responsibility. In order to ensure that students affect their own learning, the differences between each learner must be taken into consideration. The consideration of individual differences will increase
learners’ motivation (Aviram et al., 2008), give learners more interest in learning materials (Jung and Graf, 2008) and also give them the opportunity to construct, regulate and control their own learning (Johnson and Liber, 2008).

For the same reason, it is expected that a PLE will efficiently address learner needs and differences. The consideration of the diversity of individual differences brings forward the idea of a ‘Personalized Learning Environment’, or PLE for short (Olivier and Liber, 2001). A PLE, as defined by Gilbert and Han (2002), is personalized instruction that is tailored to learners’ learning style, intelligence, interests and preferences. According to Downes (2007), the PLE and Web 2.0 are for creating connections, creating content and spreading control of resources. A PLE is also created as a means for individuals to control their own learning. This feature was the primary element in the PLE that allows learners to control the materials and content being presented, the look and feel of the learning environment and the interactions with other learners (Severance, Hardin, and Whyte, 2008).

PLEs have a number of benefits over traditional teaching and learning approaches. They create a learner-centric environment rather than a teacher-centred approach. This can be seen as an opportunity to improve learners’ education process and allow them to engage actively in that process. For Green et al. (2005), the best PLE feature is when the students have the opportunity to interact with the learning objects that best fit with their needs. Therefore, the provision of learning materials that match students’ needs and differences is a crucial factor in helping students learn more effectively, based on their preferences (Aviram et al., 2008).

1.2 Background to the problem

The use of computers in the teaching and learning process has been a topic of discussion since the 1950s. Many researchers have proved the well-crafted use of computers in the learning process compared with traditional methods (Chen and Jones, 2008). This is because a computer will increase learners’ effectiveness or performance, increase their efficiency and heighten their engagement in learning.
Other than that, the computer can also promote higher order thinking skills, such as analysing, making hypotheses and inferences or solving problems by engaging students in authentic, challenging, complex and realistic tasks (NCREL, 2002; Shankar, 2008).

Largely, nowadays, the learning process has been moving towards the application of online learning (Alessi and Trollip, 2001; Liaw et al., 2007; White and Weight, 2000). What differentiates between online learning and traditional learning is the method used; however, the objectives, materials, books and syllabus are the same. Online learning, as defined by Chang and Fisher (2003), is a system and process that connects learners with materials and information that are distributed online. According to Allan and Seaman (2010), online learning occurs when the content is obtained via the online environment. Typically, there are no face-to-face meetings in the classroom. Studies conducted by them showed that, in 2008, about 4.8 million students were moving towards online learning.

One of the popular online applications that have emerged for educational use is web-based learning. Many studies have shown web-based learning’s benefits and the potential for it to enhance the teaching and learning process (Mistler-Jackson and Songer, 2000; Linn et al., 2003; Clark, 2004). This is because the use of a website as an educational tool provides learners with a new learning experience and educators with an interesting teaching environment (Nam and Smith-Jackson, 2007). The popularity of web-based learning is due to the concept of learning “anywhere” and “anytime” (Oh and Lim, 2005; Neo et al., 2008; Anido et al., 2001). As mentioned by Killedar (2008), the web can be globally distributed and has highly personalized media for delivery information so the teaching process is no longer confined to a time and place. By using this medium, time and the physical boundaries of the traditional classroom no longer exist (Khalifa and Lam, 2002).

Since online learning has different settings from the conventional classroom, educators are required to use special techniques to ensure that students learn best, based on their preferences. Therefore, educators require an understanding of the characteristics of the learners that might affect how they interact with the learning environment. This also helps educators to design an appropriate learning
environment based on students’ differences. Alomyan (2004) suggested the characteristics that educators must be concerned with, such as amount of prior knowledge of the learning domain, cognitive style, motivation, age, gender and so on. Once the profile of the learners is determined, the process of learning will be easily adapted to the student’s needs.

Currently, to cater for all the individuals’ differences in an online setting, a new concept called the Personalized Learning Environment (PLE) has emerged in the educational field. The PLE is a tool that allows learners to engage in a distributed environment consisting of a network of people, services and resources (Downes, 2006). The PLE is a new approach in designing and developing online learning instruction and is focused more on individual learning rather than the instructor, facilities, resources and tools. The PLE also plays an active role in improving the effectiveness of learning (Li and Gu, 2009). According to Atwell (2006; 2007), the PLE is an environment that is constructed by the individual and they are responsible for their own learning process. They also need to manage the process of learning effectively and take a larger stake in the ownership of content. In general, the personalized learning approach has the potential to meet educational needs in the future as well as providing a new way to encourage students to learn (Bentley and Miller, 2004).

1.2.1 Personalization and individual differences issues in online learning

Online learning has changed the ways in which education has been conducted. Unfortunately, many educational websites do not employ the principles of effective learning (Cook and Dupras, 2004). Wijekumar (2005) claimed that the web-based learning environment is a great educational tool only if it is well designed. The critical selection of learning strategies to ensure the learning takes place and how students can reflect on their learning process are examples of challenges for educators in designing an effective website (Trinidad, 2003). Hence, according to Johnson and Aragon (2003) the powerful online learning environment should consider seven aspects, which are (1) address individual differences, (2)
motivate the student, (3) avoid information overload, (4) create a real-life context, (5) encourage social interaction, (6) provide hands-on activities, and (7) encourage student reflection. For Magoulas et al. (2003), he stresses that the importance in designing web-based instructions is to accommodate individual differences amongst learners.

Many researchers claimed that the main problem with the online learning environment is the aspect of the lack of personalization (Martínez, 2000; Cristea, 2004; Rumetshofer and Wöß, 2003; Teo and Gay, 2006; Tomei, 2008; McLouglin, 1999; Ayersman and Minden, 1995). Thus, one of the key issues of concern in today’s learning is individualised learning (Wang, 2004; Santally and Senteni, 2005). According to Wang (2004), individualised learning is a learning model that places the student (learner) at the centre of the learning process. Students are active participants in their learning, which means that they learn at their own pace and use their own strategies. Thus, students are more motivated and their learning is more standardised. In addition, individual learners will take advantage of self-paced learning environments in which they have control over their pace of learning, information flow, selection of learning activities and time management (Jung, 2001).

There are many controversial issues related to the effectiveness of online instruction. Researchers claimed that online instruction lacks the ability to satisfy the diverse learning needs of online learners (Oh and Lim, 2005). Brusilovsky (2001) claimed the main problem in exploiting information in web-based learning is to determine which attributes should be used and how to attend to diverse types of learners. Chen et al. (2008) and Huang and Yang (2009) stated that most online learning materials are rarely designed to suit learners’ differences. As a result, learners tend to be ineffective in their learning process.

According to De Vita (2001), the concept of individual differences gives a challenge to educators and instructional designers to design the quality of learning materials. Moallem (2007) stated that the learning materials that match learners’ styles tend to help learners to retain information for longer. Hence, identifying different types of learner variables and their impact on student learning has been a major area of study in online instruction (Saeed et al., 2009). Donmez, Simsek and
Arikan (2010) also agreed with this, stating that knowing about learners is one of the vital factors for successful online instruction. This is because students will be able to achieve their learning goals if the pedagogical procedures are adapted to their individual differences (Federico, 2000).

When individual differences among students are being considered, the term Personalized Learning Environment (PLE) arises. Siemens (2007) defined the terms as

“...a collection of tools, brought together under the conceptual notion of openness, interoperability and learner control...PLEs are comprised of...the tools and the conceptual notions that drive how and why we select individual parts...”

Attwell (2007) stated that a PLE is a learning environment that gives an opportunity for learners to manage their own learning. In a PLE environment, the learner is accentuated in organising, customising and shaping the learning environment (Downes, 2005). It is focused on learners taking responsibility and having control over their learning, rather than being controlled by the instructor (McLoughlin and Lee, 2009). Compared with traditional learning, the PLE is more responsive to learners and considers their needs and preferences (Chatti et al., 2010). Besides, traditional learning, with its ‘one size fits all’ learning approaches, often fails to address the differences, needs and preferences amongst learners. Thus, Jafari et al. (2006) suggested learners should have a learning system that provides them with what they want and need. Hence, by using personalization it can adapt to the variety of characteristics of the students.

Research into individual differences and needs has become an important issue over the past decade. Lee (2001) believes that individuals adapt differently in web-based learning. Thus, it is expected that enhancement of the learning process can be achieved by recognising students’ learning needs, the diversification of their learning styles and students’ preferences with respect to specific learning processes. Investigations of student learning preferences have shown that among the variables that influence the success of learning are:- cognitive style (Chang, 1995, Liu and Reed, 1995; Reed and Oughton, 1997; Ford and Chen, 2000; 2001; Kim, 2001; Chen
and Paul, 2003; Alomyan, 2004), learning style (Ford and Chen, 2000; Santally, 2003), prior knowledge (Hölscherl and Strubel, 2000; Foster and Lin, 2003) and gender (Felix, 2001). Among these preferences, cognitive style and prior knowledge are commonly addressed as the individual differences in the previous research (Chen and Paul, 2003; Alomyan 2004).

1.2.2 Cognitive style as one of the individuals’ differences

Searching for information in online settings nowadays is a skill with which most students should be familiar. Previous research suggests that the skill of searching for information is related to cognitive style (Graft, 2003). Cognitive style is also one of the individual differences that is taken into account in research studies currently (Ford and Chen, 2000; 2001; Kim, 2001; Chen and Paul, 2003; Alomyan, 2004; Dag and Gecer, 2009). According to Webster (2001), cognitive style is more deep-seated in an individual’s personal and psychological behaviour. Cognitive style, as stated by researchers, is a fundamental individual difference, which relates to the preferred ways of organising and processing information and experiences (Chakraborty, Hu and Cu, 2005; Martinsen and Kaufmann, 1999; Pencheva and Papazova, 2006; Riding and Rayner, 1998; Sadler-Smith and Badger, 1998). Riding and Rayner (1998) defined cognitive style as how an individual preferred, and habitually approached, to organise and represent information. Riding (2002) claimed that cognitive style affects the ways in which events and ideas are viewed, affects how a person may respond to those events and ideas, how a person thinks about them and how a person makes a decision.

In a hypermedia system, it is important to clarify the individual’s differences, such as cognitive style (Ruttun, 2009). Among other differences, cognitive style is vital because it refers to the manner in which information is perceived and processed. Many researchers have argued cognitive style as being one of the most important factors that might affect learners’ performances, especially in computer based systems (Andris and Stueber, 1994; Ayersamn, 1993; Chang, 1995; Leader and Klein, 1996). Researchers also revealed that students with different cognitive styles
showed different learning preferences and required different navigational support in hypermedia systems (Chen and Ford, 2000). Therefore, this became a challenge to educators to consider learners’ cognitive styles when integrating information and communication technologies in a learning environment (Altun and Cakan, 2006).

Cognitive style also has a significant effect on the learning process (Cakan, 2000; Ibrahim et al., 2004) because learners with different cognitive styles have different ways of processing information. Students with high cognitive ability are assumed to be able to engage in the learning process and it also influences students’ intellectual abilities, skills and personalities (Danili and Reid, 2006). According to Cakan (2000), cognitive style is one of the significant factors that may influence students’ achievements in various subjects. A study conducted by Tinajero and Paramo (1997) to investigate the relationship between cognitive styles and students’ achievement in several subjects, such as Science, English and Mathematics, found that field independent students performed better than field dependent students. Thus, it is the educators' responsibility to consider the students' cognitive differences when involving them in the teaching and learning process, especially in the subject of Chemistry (Ibrahim et al., 2004).

1.2.3 Cognitive style in learning Chemistry

In the study of Chemistry, the learning process is not just about memorising facts but more about the application of the facts in students’ daily lives. The process of teaching and learning Chemistry should emphasise the students' ability to think about what they have learned about the chemical concepts and try to apply it in a real situation. This is consistent with the aim of Chemistry education, which stated:

"...Chemistry curriculum aims to generate students with knowledge and skills in the chemistry field and to be able to apply the knowledge and skills based on scientific attitudes and values to make decisions and solve problems in daily life."

(Pusat Perkembangan Kurikulum, 2001)
Generally, each student has different abilities and capabilities from another student. These differences include what their attitudes towards learning are, how they process information and how they respond to the learning. These differences may be influenced by their differences in types of cognitive styles. Chemistry requires students to visualise and imagine molecules when it involves the use of a model. According to Madar and Buntat (2008), the visualisation ability has a close relationship with cognitive style. Thus, students with different types of cognitive style have their own sensitivity and visualisation ability when involving the use of models in learning Chemistry. This was proved by Bailey and Garratt (2002), who that found different cognitive styles among students placed a variety of different interpretations into their lessons.

Moreover, Niaz (1987) claimed that cognitive style plays an important role in Chemistry, especially in problem solving tasks. A study conducted by Yusuf and Noraini (2010) proved that students with different cognitive styles showed different patterns when solving the given Chemistry task. For example, Field Independent (FI) students tend to analyse the questions and focus more on the given items. Field Dependent (FD) students easily understood the questions given at first but, in the end, they tended to have a problem in structuring the information again.

Other than that, cognitive style also plays an important role in Chemistry achievement (Macnaught, 1982; Tinajero and Paramo, 1998; Gerald, 2002; Danili and Reid, 2004; 2006; Bassey et al., 2007; Stamovlasisa et al., 2010). Therefore, according to Bassey (2007), there was a need to implement the recognition of students’ cognitive styles for proper understanding in the study of Chemistry. He also strongly suggested that Chemistry teachers should show greater interest in teaching this subject, using cognitive style as a way of motivating students to learn. As suggested by Ibrahim et al. (2004), in order to enhance the Chemistry learning process, an investigation into the students' cognitive styles should be carried out.
1.2.4 Difficulties in learning Chemistry

Many researchers reported about students’ difficulty in learning Chemistry. Students regard Chemistry as a difficult subject because it involves many abstract concepts and the concepts are difficult to visualise. This is supported by Sirhan (2007), who claimed that Chemistry knowledge is closely related to abstract concepts and this makes it difficult for students to learn. For Stief and Wilensky (2003), Chemistry contains many abstract concepts and requires complex concepts that are not applicable outside of the classroom. According to Taber (2002), students need an imagination and higher order thinking to learn and be proficient in chemical concepts. An understanding of chemical concepts is not only about knowing what happened, but students should also know how to apply them and explain them clearly and easily. These are the difficulties faced by students when they learn Chemistry (Sirhan, 2007).

However, it is a fact that chemical knowledge is represented at three levels, which are called sub-microscopic, macroscopic and symbolic levels (Ozmen, Ayas and Costu, 2002). These three levels are linked with each other in the *Chemistry Triangle* (Johnstone, 1991; Gabel, 1992; Harisson and Treagust, 2000; Ebenezer, 2001; Ravialo, 2001; Treagust *et al.*, 2003) (refer Figure 2.1). There are interactions and distinctions that exist between these three levels and it has become an important factor for Chemistry students to be skilled in the chemical concept. To understand the chemical concept it is necessary for students to make a connection between the three levels (Ozmen, 2008). However, students live and imagine in the macroscopic level and this causes them difficulty in following the shifts between the macroscopic and microscopic levels (Johnstone, 1991; Gabel, 1996; Harrison and Treagust, 2000; Tsaparlis, 1997; Robinson, 2003).

It is equally true that one of the most challenging features in learning Chemistry is the difficulty in visualising chemical compounds in the three chemical representation levels. Many researchers reported that students generally understand chemical phenomena at macroscopic level and are able to interpret at the symbolic level only (Hinton and Nakhleh, 1999). Conversely, students are often unable to
make a link between those two levels and the microscopic level (Jansoon, Coll and Samsook, 2009). In order to integrate the three levels of representation, students need to confront two situations. Firstly, they need to learn how to connect abstract representations (Wu, Krajcik and Soloway, 2001) and, secondly, they need to be exposed to abstract phenomena, which are difficult to interpret or visualise at the microscopic and symbolic levels (Johnstone, 1991). Robinson (2003) suggested students should have a deep understanding of how to convert a symbol to meaningful information. Only then will they be able to move towards quantitative information. This is because developing a conceptual understanding in Chemistry includes the ability to translate and represent chemical phenomena using macroscopic (observable), microscopic (particulate of matter) and symbolic forms of representation.

According to Davidowitz and Chittleborough (2009), Gabel (1996) and Nahum et al. (2004), teachers should help students to make a link between the three levels. Abdoolatiff and Narod (2009) stated that the most difficult challenges in teaching Chemistry involve conveying to students the three chemical representations when explaining chemical concepts. Thus, the teacher should provide physical examples and clear descriptions and depict the chemical diagram in colour to help students to understand and make a connection between the three representations (Davidowitz and Chittleborough, 2009). On the other hand, the use of computer-based technology, such as animation and simulation, is able to provide a powerful method for fostering chemical concepts as they can visualise simultaneous representations of the chemical phenomena (Abdoolatiff and Narod, 2009). As claimed by Tsaparlis (2009), students’ difficulties in learning Chemistry may be attributed to the fact that the topic or concept has been traditionally taught in the classroom. Hence, when students are able to depict how the three levels are connected to each other, then they are able to generate comprehensible explanations (Treagust et al., 2003) and generate relational understanding (Mulford and Robinson, 2002; Treagust et al., 2003). These will help students in reducing alternative conceptions in developing scientific mental models.
1.2.5 Models and mental models in learning Chemistry

Models are important for understanding Chemistry (Coll, 2006; Nahum et al., 2004). Models are used in all science subjects but they are particularly important in Chemistry because this subject involves so many complex and abstract concepts (Coll, 2006). According to Gilbert et al. (2000), one of Chemistry education’s goals is to teach students how to interpret models, use them and understand the nature of the model. Justi and Gilbert (2002) stated that, by using models, the understanding of chemical concepts among students, and also the ability to produce their own chemical models, might be improved. Other than that, models also help students to make a link between scientific theories and practice (Gilbert, 2005).

Chemical bonding is one of the subjects that involves the use of models, varying from simple ones to sophisticated abstract models possessing considerable mathematical complexity (Coll and Taylor, 2002; Coll and Treagust, 2003). It is a topic that students commonly find to be problematic, developing a wide range of alternative conceptions (Ozmen, 2008) (see subtopic 2.5.1). The fact is that students cannot see how the atoms or elementary particles are held together, and how they interact and bond together to form a compound. This demonstrates that learners need to understand models in chemical bonding to be proficient in Chemistry (Coll and Treagust, 2003). In 2001, Coll and Treagust reported that students at secondary, undergraduate and postgraduate levels preferred simple and realistic mental models for chemical bonding despite being exposed to abstract, mathematically complex images. Students’ misconceptions regarding these chemical bonding concepts begin when they live and operate in a macroscopic world and do not easily follow the shifts between macroscopic and microscopic levels (Harrison and Treagust, 2000). As a result, they tend to build a non-scientific mental model, which means that the idea is not aligned with scientific concepts (Taber, 2002)

Detevak (2005) developed a model called Interdependence of Three Levels of Science Concepts (ITLS) (refer Figure 2.2) to explain the connection between the concrete and the abstract level. In order to gain and build knowledge, students are encouraged to use their mental models to see the connection between all three levels.
According to Jansoon, Coll and Samsook (2009), the mental model represents ideas in an individual’s mind used to describe and explain phenomena. It allows learners to engage in description, explanation and prediction. When students learn, especially in science subjects, they will gain knowledge of the scientific mental model through the teaching process (Harrison and Treagust, 2000). This means to say that students create their own mental model and try to understand the scientific knowledge when they are involved in the learning process (Chittleborough et al., 2005).

When concerns about the three levels of representation in learning Chemistry are raised, a variety of instructional approaches, such as instructional technology (Ardac and Akaygun, 2004; Tasker and Dalton, 2006), laboratory activities (Chandrasegaran, Treagust and Mocerino, 2008) and concrete models (Copolo and Hounshell, 1995) have been used to help students understand Chemistry. For instance, multimedia tools, which integrate animations of molecular models, video clips of chemical equilibrium, or real time graphics, will provide students with opportunities to visualise chemical processes at the microscopic level. Furthermore, many studies (Ardac and Akaygun, 2004; Barnea and Dori, 2000; Sanger and Badger, 2001; Stieff, 2005; Tasker and Dalton, 2006; Tversky and Morrison, 2002; Wu, Krajcik and Soloway, 2001) found that students’ benefits, when they learned using computer-based visual models to visualise chemical processes, occurred at the three levels of representations.

1.2.6 Computer-based learning to enhance learning Chemistry

Computer-based molecular modelling is a useful and flexible tool, which enables students to view representations or phenomena that are not visible to our naked eye (Aksela and Lundell, 2008). According to Aksela and Lundell (2008), via the computer, students have a fast and easy way to make use of visual models, supported by a verbal presentation. In addition, by integrating innovative technologies, such as the computer model, it gives exposure to the micro and macro world of chemical processes (Dori and Barak, 2000). Furthermore, Condie and
Munro (2007) also highlighted that computer technology can help to enhance the understanding of abstract microscopic concepts and processes in Chemistry.

For the chemical bonding subtopic, which involves the uses of models, Kozma and Russell (2005) suggested that molecular models, simulations and animations could aid in studying the concept of bonding. Frailich, Kesner and Hofstein (2009) also agreed, saying that simulation and animation can demonstrate models at the macroscopic and microscopic levels. Ardaç and Akaygun (2005) found that students who learned with the aid of dynamic computer-based models have a better understanding of molecular representations compared with their peers who had no such experiences. Hence, the development of computer-based models to learn the three levels of representation in Chemistry is important in order to support the students’ understanding of chemical bonding, as this tool has the capacity to support the multilevel chemical concepts that are not directly perceivable by other methods.

In light of the above discussion, it has been decided to emphasise the three levels of chemical representation (macroscopic, microscopic and symbolic) in conveying chemical bonding concepts in the present study. Thus, learning materials concerned with students’ cognitive style characteristics and preferences will be developed. Additionally, by integrating this tool it is hoped to promote and help students to develop their scientific mental models in chemical bonding.

1.3 Statement of the problem

The need has arisen towards the consideration of individual differences when engaging learners in online instruction and, furthermore, in designing their learning materials. Catering to the differences amongst learners has become a crucial issue in order to ensure students engage effectively and promote their thinking in the learning process. As a result, meaningful learning will be efficiently adapted when learner differences are considered. Meaningful learning can be defined as a process in which new information is related to previous knowledge within the cognitive structure of the learner (Novak, 2002; Viola et.al, 2007). Nevertheless, the process of teaching
and learning will be more meaningful when teachers know their students’ unique styles, needs, preferences, strengths and weaknesses in learning. Hence, educators need to understand the individual differences between students, such as cognitive style. This is because individuals are different in their ways of seeking and processing information. Therefore, the PLE that has emerged in the education field recently tends to cater to the individual’s differences, such as learning style, cognitive style, skills, prior knowledge and many more (Sampson and Karagiannidis, 2004)

Students have their own needs, preferences and characteristics and these are categorised as individual differences. Among the individual difference variables that are considered important is that of cognitive style. In the context of Chemistry, cognitive style seems to have a significant effect on students’ achievements (Stamovlasisa et al., 2010). However, Chemistry is one of the most difficult subjects to learn (Chittleborough, 2004). Many students regard Chemistry as being too abstract, too hard and too mathematical. As a result, students claim that the subject is boring (Gilbert, 2002) and they develop a negative attitude towards it. Once students have decided that something is going to be hard to learn, they end up with many misconceptions about the subject.

Chemistry has been found by many researchers to generate misconceptions among students. In fact, learning Chemistry is not easy, as many people think, even though Chemistry concepts are related to our daily life. Brousseau (2005) claimed that the abstract nature of Chemistry and its three levels, macroscopic, microscopic and symbolic, are the causes of difficulty in learning it. The macroscopic level refers to observable phenomena, or things that we can see, touch and feel. Chemical representation at the microscopic level refers to chemistry concepts behind the phenomena, and these are often abstract. The symbolic level is used to represent chemistry concepts, such as symbols, formulas and structures. Mbajiorgu and Red (2006) stated that these three levels are the main reason why students find Chemistry difficult. These authors also claimed that the interaction between these three levels requires learners to manipulate chemistry concepts in order for understanding to take place.
One of the Chemistry topics that require students to understand the three levels is the Chemical Bond. In science education literature, there have been numerous studies to determine students’ understanding and misconceptions about chemical bonding. According to Harrison and Treagust (2000), students’ misconceptions of this topic start with the fact that they live in macroscopic matter and cannot follow the shift between the macroscopic and microscopic levels. As a result, students tend to build nonscientific mental models. Other than that, Ozmen (2004) also stated that chemical bonding involves the use of a variety of models, from simple, analogical models to sophisticated, abstract models. In fact, the use of models is dominant in the subject of Chemistry (Nahum et al., 2004). When students are exposed to the use of models, they will form a mental model as a result of the learning process (Harrison and Treagust, 2000). However, the difficulties arise when students are not able to explain the shift of chemical representations in the Chemistry triangle and, at last, they will develop a non-scientific mental model (Taber, 2002). In a study conducted by Coll and Treagust (2001), with secondary, undergraduate and postgraduate students, they found that all respondents were able to explain the concept of bonding with a simple explanation only. In addition, they found that the learners’ mental models of bonding became sophisticated and complex when they were asked to explain more detail about the formation of bonding.

As a conclusion, research into individual differences, in cognitive styles and also in the difficulties of learning Chemistry related to chemical bonding, are widely accepted among the educational researchers. All of these three issues have their own problems and crises. However, there is still little research focussing on these three aspects together in online learning. Thus, to put it briefly, this study was designed to focus on cognitive styles and the students’ personalized aspects, with the web-based learning environment as the platform for the students to learn chemical bonding. In addition, more research only focused on the effect of cognitive styles on students’ achievements. For that reason, the aim of this research is to design and develop chemical bonding learning materials based on cognitive style characteristics and to investigate further the effect on students’ mental model development and their interaction pattern while learning using the website.
1.4 Objectives of the study

The objectives of this research are:

i. To design and develop a Chemistry website for the chemical bonding subtopic based on the students’ cognitive styles, which are field dependent and field independent (Witkin, 1971).

ii. To investigate the influence of a cognitive style based website (field dependent and field independent) in promoting students’ achievements in:
   a. Learning the chemical bonding topic
   b. Development of the mental model in chemical bonding

iii. To study the development of the mental model for field dependent and field independent students while learning using the website.

iv. To examine the pattern of interaction for field dependent and field independent students while learning using the website and its contribution towards the mental model development.

1.5 Research questions

The research questions of this study are:

i. Is the cognitive style based website influential in promoting students’ achievements in:
   a. Learning the chemical bonding topic?
   b. Development of the mental model in chemical bonding?

ii. What is the development of the mental model for field dependent and field independent students while learning using the website?

iii. What is the pattern of interaction for field dependent and field independent students while learning using the website and how does it contribute to the mental model development?
1.6 Theoretical framework

The theoretical framework is presented in Figure 1.1. The PLE forms the learning environment being implemented of this research. As mentioned by Freitas and Yap (2005), today the “one size fits all” approach has changed to a more personalized approach to meet the individual’s needs and preferences. The belief that individuals learn differently is one of the main considerations of the modern theories in education nowadays. Hence, the focus on individual needs illustrates the clear connection between the PLE and individual differences amongst learners.

Cognitivist and constructivist theorists have considered learning and instruction related to individual differences (Yecan, 2005). According to Sampson, Karagiannidis and Kinshuk (2002), the PLE also evolved from both of these theories. Many studies were conducted to find out how individuals’ differences affect the learning process in the online setting (Yecan, 2005). Chen and Paul (2003) stated that, nowadays, the pattern of research has shifted from investigating how web-based instruction affects students’ achievements to being more focused on how individual differences affect the learning process and the environment as well.

When individuals learn in a hypermedia environment, they are engaged in constructing knowledge that is focused on how they organise and process the information. This ability is related to their cognitive style (Chen, 2002). Cognitive styles are also considered as one of the individual differences that were found to be important and have significance for students’ learning, especially in a hypermedia environment (Chang, 1995; Yecan, 2005; Lee and Boling, 2008).

In this present research, the cognitive styles defined by Witkin et al. (1971) of being field dependent (FD) and field independent (FI) are chosen. According to Fitzgerald and Semrau (1998), the FDI is one of the factors contributing to the development of operative schemata in individuals’ cognitive structure, which is one of the stages in the mental model (Jonassen, Beissner and Yacci, 1993).
Personalized Learning Environment (PLE)

Individual Differences

Cognitive styles
Witkin et al. (1971)
-Field Independent (FI)
-Field Dependent (FD)

Mental Model Development

Personalized Learning Materials

The Interdependence of Three Levels of Science Concepts model (Detevak, 2005)

Figure 1.1: Theoretical Framework
In a Chemistry context, the mental model is a personal representation in integrating the macroscopic, microscopic and symbolic levels. A model called the Interdependence of Three Levels of Science Concepts (ITLS), developed by Detevak (2005), illustrates the connection of these three levels in chemical representation for developing a mental model. According to Detevak (2005), learners will develop their mental model when they are able to see the connection between the three levels in chemical representations.

Therefore, by considering all these aspects, personalized learning materials will be the expected outcome, catering for cognitive style characteristics in order to promote the development of the mental model in the three levels of chemical representations (the macroscopic, microscopic and symbolic level).

1.7 Research Framework

This research were conducted according to the research framework illustrated in Figure 1.2. Initially, the characteristics of the field dependent (FD) and field independent (FI) types of cognitive style were investigated. The characteristics were then considered in the design and development process of the learning materials on the Chemical Bond website. Prior analysis has explained that the development of the mental model among students in learning Chemistry depended heavily on the students’ understanding of the three levels of chemical representations, the macroscopic, microscopic and symbolic levels. Detevak (2005) claimed that the scientific mental model would be developed if students were able to see the connection between those three levels and, furthermore, able to explain the shift between it. Thus, the Chemical Bond website is developed for the purpose of promoting the development of the mental model in chemical bonding by considering students’ cognitive style characteristics as their personalized aspect.

In the implementation phase, the developed website is used by students to learn the chemical bonding topic. From this process, the research expected to investigate the students’ achievements in learning chemical bonding and the mental
model development in this topic. Instead of that, upon the implementation of the website, the students’ weekly mental model development is investigated deeply and the students’ log data is obtained. Finally, the influence of the website in promoting the students’ achievements and development of the mental model in chemical bonding is investigated in the evaluation phase. Furthermore, the data in the students’ log files is further analysed to construct the pattern of interaction for both types of students (FD and FI).

**Figure 1.2: Research Framework**

1.8 **Rationale for the study**

For this study, the aim of applying the concept of PLE is due to the emergence from Web 1.0 to Web 2.0. The characteristics of Web 2.0 emphasise the concept of learning not being limited to time, place and other restrictions but tailored to individual needs, knowledge, interests and background (Sampson and Karagiannidis, 2002). In addition, the Web 2.0 features provide opportunities for students to control their own learning process (Dron, 2007) and this advantage is consistent with the characteristics of the PLE concept. Furthermore, the PLE concept may satisfy learners according to their needs, preferences and characteristics.
There are varieties of individual differences that can be considered by educators in providing the learning environment more effectively. However, the cognitive style is the most addressed individual difference indicator by researchers. Cognitive style is one of the preferences that have an impact in the process of decision-making and creative cognitive processing (Steele, 2003). In learning a science subject, such as Chemistry, cognitive style affects an individual's personality and the psychological behaviours that indicate how learners perceive, interact and respond to the learning environment (Fatt, 2000). Accordingly, cognitive style also has an impact on learners' performance and achievement in Chemistry (Danili and Reid, 2006).

Since students regard Chemistry as an uninteresting subject and one that is difficult to learn, especially in interpreting chemical processes at a macroscopic, microscopic and symbolic level, educators need to apply an effective strategy in their teaching process. This will help students to become proficient in the chemical concept. Empirical evidence has documented that educators can make Chemistry lessons more interesting and exciting by using multimedia teaching materials, which are inherent with the potential to visualise abstract concepts in Chemistry. Thus, when students are able to visualise those three levels in order to explain the process involved, they may end up with an appropriate mental model.

Therefore, the relevance of this study is to focus on the chemical bonding subtopic, because of the past studies that have proved that there are many difficulties faced by students, as well as the need to form a mental model that is consistent with the concept of science. Hence, the idea of doing this research on the development of mental models, particularly in the chemical bonding subtopic, is based on the facts and the evidence from previous studies. Additionally, the implementation of the concept of personalized learning, with the focus on the cognitive style aspect, hopes to provide an effective learning environment for the students as well as to improve their performance.
1.9 Importance of the study

The importance of this study is to all people who are involved in the process of teaching and learning. They are:-

1.9.1 Students

Students can recognise their preferred learning style based on their cognitive style characteristics. By knowing this, their motivation will increase during the learning process. Other than that, the students will know their strengths and weaknesses. This is proved by Smith and Dalton (2005), who stated that learners who understand their own style would learn more effectively. Furthermore, learners who know their own learning style or preferences will make relevant choices about what to engage with and what learning resources are likely to be attractive and useful.

1.9.2 Teachers

In responding to such individual differences among students, teachers should use alternative and creative teaching techniques in order to increase students’ motivation and grab their attention. Perhaps, this research will help teachers by giving them ideas to plan a creative teaching method based on their students’ cognitive style. Otherwise, teachers can also design their teaching activities and materials according to students’ preferences.

1.9.3 The Government

The information gathered from this study could help the Ministry in developing a new curriculum. It is hoped that the government will change to a
teaching system or curriculum that emphasises the individual differences among students, so that students would be able to learn effectively. This research can also provide a helpful framework as a guideline to integrate learning styles in teaching and learning modules, especially in the subject of Chemistry. This is because the importance of Chemistry is becoming more apparent with a growing awareness of such areas as Environmental Chemistry, Nanotechnology, Food Analysis, Pest Control, Cosmetics, Medicine and Forensic Science (Cittleborough, 2004).

1.9.4 Parents

This research will help parents to recognise their children’s preferences and cognitive styles as well and it is important for every parent to know what their children’s learning preferences are. When parents understand which learning styles their children have, they are able to connect with their children on a deeper and more meaningful level and they will more quickly be able to teach them effectively at home.

1.10 Scope and research delimitation

This research is focussed on Form 4 students who are learning the chemical bond subtopic, based on the Integrated Curriculum for Secondary School (KBSM). The students are selected from those who are studying Chemistry in a secondary school in Johor Bahru. The research is to investigate the individuals’ differences, with attention to the cognitive styles, proposed by Witkin et al. (1971), of Field Independence (FI) and Field Dependence (FD). In this research, attention was focused on these two types of cognitive style because they are dominant over the other cognitive styles in the literature (Danili and Reid, 2006) and are also one of the numerous factors studied in the research of learning through hypermedia systems (Kim, 2001). The students’ cognitive styles will be determined using the Group Embedded Figures Test (GEFT) devised by Witkin et al. (1971). Furthermore, for interaction purposes, this study implements five learner-centred interaction types,
which are the Learner-interface interaction, the Learner-self interaction, the Learner-content interaction, the Learner-instructor interaction and the Learner-learner interaction (Chou et al., 2010).

1.11 Operational Definition

There are several terminologies frequently used in this research, which are:-

1.11.1 Personalized learning environment (PLE)

According to Schaffert and Hilzensauer (2008), PLE is the sum of all the tools used (e-mail, browser, websites and applications). It is a technological realisation, where social software applications and web services are combined, for example, as a ‘mash-up’ in a single portal for the purpose of learning. Contrary to conventional instruction, in PLE the materials and learning sequence are dependent on the learner's characteristics, such as learning styles, skills, interests etc. (Sampson, Karagiannidis and Kinshuk, 2002). Riecken (2000) stated that personalization helps teachers to build a meaningful one-to-one relationship with students by understanding their needs and helps students to reach a goal, because their individual needs are fully addressed in a given context. However, in this study, the personalization term refers to the personalized learning materials that are designed and developed by considering students’ cognitive style characteristics (FD and FI). By giving students the learning materials that were designed based on their characteristics, it is hope that it will contribute to their scientific mental model development.

1.11.2 Cognitive styles

There are many cognitive style dimensions, such as field dependent vs. field independent, analytic vs. holistic and convergent vs. divergent. However, this study
is focused on field dependent (FD) and field independent (FI), as proposed by Witkin and his friends in 1971. A widely cited definition, based on Witkin et al. (1971), defined cognitive style as the characteristic self-consistent modes of functioning that individuals show in their perceptual and intellectual activities. Alternatively, according to Lee (2007), cognitive style is an individual’s preferred and habitual mode of perception, imagery, organisation and elaboration during knowledge acquisition or the problem solving process.

According to Riding and Cheema (1991), an FI person is one that has less difficulty in separating the most essential information from its context and is more likely to be influenced by internal than external cues and to be selective in their information input. By contrast, an FD person has difficulty in separating incoming information from its contextual surrounding and is more likely to be influenced by external cues and to be non-selective in their information uptake.

1.11.3 Mental Model

The mental model describes a cognitive mechanism for representing and making inferences about a system or a problem, which the user builds as he or she interacts with and learns about the system (Borgman, 1986). In addition, Gilbert (2005) stated that the mental model is an abstract concept that cannot directly be observed. Furthermore, mental models are purely abstract descriptions of memory; they are dynamic representations that change over time. However, referring to the context of Chemistry, the mental model is a personal representation of the microscopic level of matter (Cittleborough, 2004). In this study, this term is based on mental activities in the students’ minds to describe the chemical concept involved at macroscopic, microscopic and symbolic level.
1.11.4 Achievement

According to the Oxford Dictionary 4th edition, achievement is referred to as something accomplished, especially by superior ability, special effort, great courage etc. In this area of study, achievement refers to the improvement of students’ knowledge after the learning process had occurred.

1.11.5 Representation

As stated by Chittleborough (2004), representation means something that represents another thing. Representations come in a huge variety of forms and usually help the learner to construct a personal mental model.

1.11.6 Interaction

The classic definition of interaction by Moore (1989) is when a sender and a receiver connect in three types of interaction: learner-content, learner-instructor and learner–learner. Muirhead and Juwah (2004) described interaction as a dialogue, or discourse, or event between two or more participants and objects, which occurs synchronously and/or asynchronously, mediated by response or feedback and interfaced by technology. In this present research, the students’ interaction with their peers, teachers, content, interface and, also, with themselves are obtained upon the implementation of the website using the data logging file, which is based on the interaction framework proposed by Chou et al. (2010).

1.12 Summary

This chapter has discussed how education emphasises the issue of technology and then moves from ICT to online learning and, finally, the rise of the personalized
learning concept. This issue comes to mind when the needs of individual differences amongst students should be taken into account in the process of teaching and learning. In addition, studies showed that individual differences have a significant relationship with students’ achievements. Hence, educators need to develop an educational environment that will appeal to the individual differences among students. Perhaps, the PLE has the potential to provide a new environment that allows students to explore learning in their context and the experiences will enrich their process in gaining new knowledge.


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